

COMPOUNDS, COMPOSITIONS, AND METHODS

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application number 60/470,729, filed May 14, 2003, which is incorporated herein by reference for all purposes.

FIELD OF THE INVENTION

[0002] This invention relates to compounds which are inhibitors of the mitotic kinesin KSP and are useful in the treatment of cellular proliferative diseases, for example cancer, hyperplasias, restenosis, cardiac hypertrophy, immune disorders, fungal disorders, and inflammation.

BACKGROUND OF THE INVENTION

[0003] Among the therapeutic agents used to treat cancer are the taxanes and vinca alkaloids, which act on microtubules. Microtubules are the primary structural element of the mitotic spindle. The mitotic spindle is responsible for distribution of replicate copies of the genome to each of the two daughter cells that result from cell division. It is presumed that disruption of the mitotic spindle by these drugs results in inhibition of cancer cell division, and induction of cancer cell death. However, microtubules form other types of cellular structures, including tracks for intracellular transport in nerve processes. Because these agents do not specifically target mitotic spindles, they have side effects that limit their usefulness.

[0004] Improvements in the specificity of agents used to treat cancer is of considerable interest because of the therapeutic benefits which would be realized if the side effects associated with the administration of these agents could be reduced. Traditionally, dramatic improvements in the treatment of cancer are associated with identification of therapeutic agents acting through novel mechanisms. Examples of this include not only the taxanes, but also the camptothecin class of topoisomerase I inhibitors. From both of these perspectives, mitotic kinesins are attractive targets for new anti-cancer agents.

[0005] Mitotic kinesins are enzymes essential for assembly and function of the mitotic spindle, but are not generally part of other microtubule structures, such as in nerve processes. Mitotic kinesins play essential roles during all phases of mitosis. These enzymes are "molecular motors" that transform energy released by hydrolysis of ATP into mechanical force which drives the directional movement of cellular cargoes along microtubules. The catalytic domain sufficient for this task is a compact structure of approximately 340 amino acids. During mitosis, kinesins organize microtubules into the bipolar structure that is the mitotic spindle. Kinesins mediate movement of chromosomes along spindle microtubules, as well as structural changes in the mitotic spindle associated with specific phases of mitosis. Experimental perturbation of mitotic kinesin function causes malformation or dysfunction of the mitotic spindle, frequently resulting in cell cycle arrest and cell death.

[0006] Among the mitotic kinesins which have been identified is KSP. KSP belongs to an evolutionarily conserved kinesin subfamily of plus end-directed microtubule motors that assemble into bipolar homotetramers consisting of antiparallel homodimers. During mitosis KSP associates with microtubules of the mitotic spindle. Microinjection of antibodies directed against KSP into human cells prevents spindle pole separation during prometaphase, giving rise to monopolar spindles and causing mitotic arrest and induction of programmed cell death. KSP and related kinesins in other, non-human, organisms, bundle antiparallel microtubules and slide them relative to one another, thus forcing the two spindle poles apart. KSP may also mediate in anaphase B spindle elongation and focussing of microtubules at the spindle pole.

[0007] Human KSP (also termed HsEg5) has been described (Blangy, et al., Cell, 83:1159-69 (1995); Whitehead, et al., Arthritis Rheum., 39:1635-42 (1996); Galgio et al., J. Cell Biol., 135:339-414 (1996); Blangy, et al., J Biol. Chem., 272:19418-24 (1997); Blangy, et al., Cell Motil Cytoskeleton, 40:174-82 (1998); Whitehead and Rattner, J. Cell Sci., 111:2551-61 (1998); Kaiser, et al., JBC 274:18925-31 (1999); GenBank accession numbers: X85137, NM004523 and U37426), and a fragment of the KSP gene (TRIP5) has been described (Lee, et al., Mol Endocrinol., 9:243-54 (1995); GenBank accession number L40372). Xenopus KSP homologs (Eg5), as well as Drosophila KLP61 F/KRP130 have been reported.

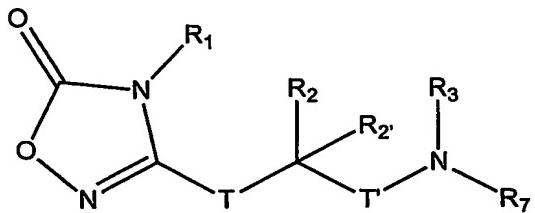
[0008] Mitotic kinesins, including KSP, are attractive targets for the discovery

and development of novel antimitotic chemotherapeutics. Accordingly, it is an object of the present invention to provide compounds, compositions and methods useful in the inhibition of KSP.

SUMMARY OF THE INVENTION

[0009] In accordance with the objects outlined above, the present invention provides compounds that can be used to treat cellular proliferative diseases. The compounds are KSP inhibitors. The present invention also provides compositions comprising such compounds, and methods utilizing such compounds or compositions, which can be used to treat cellular proliferative diseases.

[0010] In one aspect, the invention relates to methods for treating cellular proliferative diseases, and for treating disorders by inhibiting the activity of KSP. The methods employ one or more compounds represented by Formula I:



Formula I

wherein:

T and T' are independently a covalent bond or optionally substituted lower alkylene;

R₁ is hydrogen, optionally substituted alkyl-, optionally substituted aryl-, optionally substituted aralkyl-, optionally substituted heteroaryl-, or optionally substituted heteroaralkyl-;

R₂ and R_{2'} are independently hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl; or R₂ and R_{2'} taken together form an optionally

substituted 3- to 7-membered ring which optionally incorporates from one to two heteroatoms, selected from N, O, and S in the ring;

R₃ is hydrogen, optionally substituted alkyl-, optionally substituted aryl-, optionally substituted aralkyl-, optionally substituted heteroaryl-, optionally substituted heteroaralkyl-, -C(O)-R₆, or -S(O)₂-R_{6a};

R₆ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, optionally substituted heteroaralkyl, R₄O- or R₅-NH-;

R_{6a} is optionally substituted alkyl, optionally substituted aryl, optionally substituted alkylaryl, optionally substituted heteroaryl, optionally substituted alkylheteroaryl, or R₅-NH-;

R₇ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl;

or R₇ taken together with R₃, and the nitrogen to which they are bound, form an optionally substituted 5- to 12-membered nitrogen-containing heterocycle, which optionally incorporates from one to two additional heteroatoms, chosen from N, O, and S in the heterocycle ring;

or R₇ taken together with R₂ form an optionally substituted 5- to 12-membered nitrogen-containing heterocycle, which optionally incorporates from one to two additional heteroatoms, chosen from N, O, and S in the heterocycle ring;

R₄ is optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl; and

R₅ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl;

(Formula I including single stereoisomers and mixtures of stereoisomers);
a pharmaceutically acceptable salt of a compound of Formula I;
a pharmaceutically acceptable solvate of a compound of Formula I; or
a pharmaceutically acceptable solvate of a pharmaceutically acceptable salt of a compound of Formula I.

[0011] In one aspect, the invention relates to methods for treating cellular

proliferative diseases and other disorders that can be treated by inhibiting KSP by the administration of a therapeutically effective amount of a compound of Formula I; a pharmaceutically acceptable salt of a compound of Formula I; a pharmaceutically acceptable solvate of a compound of Formula I; or a pharmaceutically acceptable solvate of a pharmaceutically acceptable salt of a compound of Formula I. Such diseases and disorders include cancer, hyperplasia, restenosis, cardiac hypertrophy, immune disorders, fungal disorders and inflammation.

[0012] In another aspect, the invention relates to compounds useful in inhibiting KSP kinesin. The compounds have the structures shown above in Formula I; a pharmaceutically acceptable salt of a compound of Formula I; a pharmaceutically acceptable solvate of a compound of Formula I; or a pharmaceutically acceptable solvate of a pharmaceutically acceptable salt of a compound of Formula I. The invention also relates to pharmaceutical compositions comprising: a therapeutically effective amount of a compound of Formula I; a pharmaceutically acceptable salt of a compound of Formula I; a pharmaceutically acceptable solvate of a compound of Formula I; or a pharmaceutically acceptable solvate of a pharmaceutically acceptable salt of a compound of Formula I; and one or more pharmaceutical excipients. In another aspect, the composition further comprises a chemotherapeutic agent other than a compound of the present invention.

[0013] In an additional aspect, the present invention provides methods of screening for compounds that will bind to a KSP kinesin, for example compounds that will displace or compete with the binding of a compound of the invention. The methods comprise combining a labeled compound of the invention, a KSP kinesin, and at least one candidate agent and determining the binding of the candidate agent to the KSP kinesin.

[0014] In a further aspect, the invention provides methods of screening for modulators of KSP kinesin activity. The methods comprise combining a compound of the invention, a KSP kinesin, and at least one candidate agent and determining the effect of the candidate agent on the KSP kinesin activity.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

[0015] As used in the present specification, the following words and

phrases are generally intended to have the meanings as set forth below, except to the extent that the context in which they are used indicates otherwise. The following abbreviations and terms have the indicated meanings throughout:

Ac	=	acetyl
Bn	=	benzyl
Boc	=	t-butylcarbonyl
Bu	=	butyl
c-	=	cyclo
CBZ	=	carbobenzoxy = benzyloxycarbonyl
CDI	=	1,1-carbonyldi-imidazole
DCM	=	dichloromethane = methylene chloride = CH ₂ Cl ₂
DIEA	=	DIPEA = N,N-diisopropylethylamine
DMF	=	N,N-dimethylformamide
DMSO	=	dimethyl sulfoxide
Et	=	ethyl
h	=	hr = hour
HOAc	=	acetic acid
Me	=	methyl
mesyl	=	methanesulfonyl
min	=	minute
NMM	=	N-methylmorpholine
Ph	=	phenyl
Py	=	pyridine
rt	=	room temperature
sat'd	=	saturated
s-	=	secondary
t-	=	tertiary
TEA	=	triethylamine
TFA	=	trifluoroacetic acid
THF	=	tetrahydrofuran

[0016] Alkyl is intended to include linear, branched, or cyclic aliphatic hydrocarbon structures and combinations thereof, which structures can be saturated or

unsaturated. **Lower-alkyl** refers to alkyl groups of from 1 to 5 carbon atoms, preferably from 1 to 4 carbon atoms. Examples of lower-alkyl groups include methyl-, ethyl-, propyl-, isopropyl-, butyl-, s-and t-butyl and the like. Preferred alkyl groups are those of C₂₀ or below. More preferred alkyl groups are those of C₁₃ or below.

Cycloalkyl is a subset of alkyl and includes cyclic aliphatic hydrocarbon groups of from 3 to 13 carbon atoms. Examples of cycloalkyl groups include c- propyl-, c- butyl-, c-pentyl-, norbornyl-, adamantyl and the like. **Cycloalkyl-alkyl-** is another subset of alkyl and refers to cycloalkyl attached to the parent structure through a non-cyclic alkyl-. Examples of cycloalkyl-alkyl- include cyclohexylmethyl-, cyclopropylmethyl-, cyclohexylpropyl-, and the like. In this application, alkyl includes alkanyl-, alkenyl and alkynyl residues; it is intended to include vinyl-, allyl-, isoprenyl and the like. When an alkyl residue having a specific number of carbons is named, all geometric isomers having that number of carbons are intended to be encompassed; thus, for example, "butyl" is meant to include n-butyl-, sec-butyl-, isobutyl and t-butyl-; "propyl" includes n-propyl-, isopropyl-, and c-propyl-.

[0017] **Alkylene-, alkenylene-, and alkynylene-** are other subsets of alkyl-, including the same residues as alkyl-, but having two points of attachment within a chemical structure. Examples of alkylene include ethylene (-CH₂CH₂-), propylene (-CH₂CH₂CH₂-), dimethylpropylene (-CH₂C(CH₃)₂CH₂-) and cyclohexylpropylene (-CH₂CH₂CH(C₆H₁₃)-). Likewise, examples of alkenylene include ethenylene (-CH=CH-), propenylene (-CH=CH-CH₂-), and cyclohexylpropenylene (-CH=CHCH(C₆H₁₃)-). Examples of alkynylene include ethynylene (-C≡C-) and propynylene (-CH≡CH-CH₂-).

[0018] **Cycloalkenyl** is a subset of alkyl and includes unsaturated cyclic hydrocarbon groups of from 3 to 13 carbon atoms. Examples of cycloalkenyl groups include c-hexenyl-, c-pentenyl and the like.

[0019] **Alkoxy or alkoxyl** refers to an alkyl group, preferably including from 1 to 8 carbon atoms, of a straight, branched, or cyclic configuration, or a combination thereof, attached to the parent structure through an oxygen (i.e., the group alkyl-O-). Examples include methoxy-, ethoxy-, propoxy-, isopropoxy-, cyclopropoxy-, cyclohexyloxy- and the like. **Lower-alkoxy** refers to alkoxy groups containing one to four carbons.

[0020] **Acyl** refers to groups of from 1 to 8 carbon atoms of a straight,

branched, or cyclic configuration or a combination thereof, attached to the parent structure through a carbonyl functionality. Such groups may be saturated or unsaturated, and aliphatic or aromatic. One or more carbons in the acyl residue can be replaced by oxygen, nitrogen (e.g., carboxamido), or sulfur as long as the point of attachment to the parent remains at the carbonyl. Examples include acetyl-, benzoyl-, propionyl-, isobutyryl-, oxanyl-, t-butoxycarbonyl-, benzyloxycarbonyl, morpholinylcarbonyl, and the like. **Lower-acyl** refers to acyl groups containing one to four carbons.

[0021] **Amino** refers to the group -NH₂. The term “substituted amino” refers to the group -NHR or -NRR where each R is independently chosen from the group: optionally substituted alkyl-, optionally substituted alkoxy, optionally substituted aminocarbonyl-, optionally substituted aryl-, optionally substituted heteroaryl-, optionally substituted heterocyclyl-, acyl-, alkoxycarbonyl-, sulfanyl-, sulfinyl and sulfonyl-, e.g., diethylamino, methylsulfonylamino, furanyl-oxy-sulfonamino. Substituted amino includes the groups -NR^cCOR^b, -NR^cCO₂R^a, and -NR^cCONR^bR^c, where

R^a is an optionally substituted C₁-C₆ alkyl-, aryl-, heteroaryl-, aryl-C₁-C₄ alkyl-, or heteroaryl-C₁-C₄ alkyl- group;

R^b is H or optionally substituted C₁-C₆ alkyl-, aryl-, heteroaryl-, aryl-C₁-C₄ alkyl-, or heteroaryl-C₁-C₄ alkyl- group; and

R^c is hydrogen or C₁-C₄ alkyl-; and

where each optionally substituted R^b group is independently unsubstituted or substituted with one or more substituents independently chosen from C₁-C₄ alkyl-, aryl-, heteroaryl-, aryl-C₁-C₄ alkyl-, heteroaryl-C₁-C₄ alkyl-, C₁-C₄ haloalkyl-, -OC₁-C₄ alkyl, -OC₁-C₄ alkylphenyl, -C₁-C₄ alkyl-OH, -OC₁-C₄ haloalkyl, halogen, -OH, -NH₂, -C₁-C₄ alkyl-NH₂, -N(C₁-C₄ alkyl)(C₁-C₄ alkyl), -NH(C₁-C₄ alkyl), -N(C₁-C₄ alkyl)(C₁-C₄ alkylphenyl), -NH(C₁-C₄ alkylphenyl), cyano, nitro, oxo (as a substituent for heteroaryl), -CO₂H, -C(O)OC₁-C₄ alkyl, -CON(C₁-C₄ alkyl)(C₁-C₄ alkyl), -CONH(C₁-C₄ alkyl), -CONH₂, -NHC(O)(C₁-C₄ alkyl), -NHC(O)(phenyl), -N(C₁-C₄ alkyl)C(O)(C₁-C₄ alkyl), -N(C₁-C₄ alkyl)C(O)(phenyl), -C(O)C₁-C₄ alkyl, -C(O)C₁-C₄ phenyl, -C(O)C₁-C₄ haloalkyl, -OC(O)C₁-C₄ alkyl, -SO₂(C₁-C₄ alkyl), -SO₂(phenyl), -SO₂(C₁-C₄ haloalkyl), -SO₂NH₂, -SO₂NH(C₁-C₄ alkyl), -SO₂NH(phenyl), -

NHSO₂(C₁-C₄ alkyl), -NHSO₂(phenyl), and -NHSO₂(C₁-C₄ haloalkyl).

[0022] **Antimitotic** refers to a drug for inhibiting or preventing mitosis, for example, by causing metaphase arrest. Some antitumour drugs block proliferation and are considered antimitotics.

[0023] **Aryl** and **heteroaryl** mean a 5- or 6-membered aromatic or heteroaromatic ring containing 0 or 1-4 heteroatoms, respectively, chosen from O, N, or S; a bicyclic 9- or 10-membered aromatic or heteroaromatic ring system containing 0 or 1-4 (or more) heteroatoms, respectively, chosen from O, N, or S; or a tricyclic 12- to 14-membered aromatic or heteroaromatic ring system containing 0 or 1-4 (or more) heteroatoms, respectively, chosen from O, N, or S. The aromatic 6- to 14-membered carbocyclic rings include, e.g., phenyl-, naphthyl-, indanyl-, tetralinyl-, and fluorenyl and the 5- to 10-membered aromatic heterocyclic rings include, e.g., imidazolyl-, pyridinyl-, indolyl-, thienyl-, benzopyranonyl-, thiazolyl-, furanyl-, benzimidazolyl-, quinolinyl-, isoquinolinyl-, quinoxaliny-, pyrimidinyl-, pyrazinyl-, tetrazolyl and pyrazolyl-.

[0024] **Aralkyl-** refers to a residue in which an aryl moiety is attached to the parent structure via an alkyl residue. Examples include benzyl-, phenethyl-, phenylvinyl-, phenylallyl and the like. **Heteroaralkyl-** refers to a residue in which a heteroaryl moiety is attached to the parent structure via an alkyl residue. Examples include furanymethyl-, pyridinylmethyl-, pyrimidinylethyl and the like.

[0025] **Aralkoxy-** refers to the group -O-aralkyl. Similarly, **heteroaralkoxy-** refers to the group -O-heteroaralkyl-; **aryloxy-** refers to the group -O-aryl-; **acyloxy-** refers to the group -O-acyl-; **heteroaryloxy-** refers to the group -O-heteroaryl-; and **heterocyclloxy-** refers to the group -O-heterocyclyl (i.e., aralkyl-, heteroaralkyl-, aryl-, acyl-, heterocycl-, or heteroaryl is attached to the parent structure through an oxygen).

[0026] **Carboxyalkyl-** refers to the group -alkyl-COOH.

[0027] **Aminocarbonyl** refers to the group -CONR^bR^c, where

R^b is H or optionally substituted C₁-C₆ alkyl-, aryl-, heteroaryl-, aryl-C₁-C₄ alkyl-, or heteroaryl-C₁-C₄ alkyl- group; and

R^c is hydrogen or C₁-C₄ alkyl-; and

where each optionally substituted R^b group is independently unsubstituted or substituted with one or more substituents independently chosen from C₁-C₄ alkyl-,

aryl-, heteroaryl-, aryl-C₁-C₄ alkyl-, heteroaryl-C₁-C₄ alkyl-, C₁-C₄ haloalkyl-, -OC₁-C₄ alkyl-, -OC₁-C₄ alkylphenyl, -C₁-C₄ alkyl-OH, -OC₁-C₄ haloalkyl, halogen, -OH, -NH₂, -C₁-C₄ alkyl-NH₂, -N(C₁-C₄ alkyl)(C₁-C₄ alkyl), -NH(C₁-C₄ alkyl), -N(C₁-C₄ alkyl)(C₁-C₄ alkylphenyl), -NH(C₁-C₄ alkylphenyl), cyano, nitro, oxo (as a substituent for heteroaryl), -CO₂H, -C(O)OC₁-C₄ alkyl, -CON(C₁-C₄ alkyl)(C₁-C₄ alkyl), -CONH(C₁-C₄ alkyl), -CONH₂, -NHC(O)(C₁-C₄ alkyl), -NHC(O)(phenyl), -N(C₁-C₄ alkyl)C(O)(C₁-C₄ alkyl), -N(C₁-C₄ alkyl)C(O)(phenyl), -C(O)C₁-C₄ alkyl, -C(O)C₁-C₄ phenyl, -C(O)C₁-C₄ haloalkyl, -OC(O)C₁-C₄ alkyl, -SO₂(C₁-C₄ alkyl), -SO₂(phenyl), -SO₂(C₁-C₄ haloalkyl), -SO₂NH₂, -SO₂NH(C₁-C₄ alkyl), -SO₂NH(phenyl), -NHSO₂(C₁-C₄ alkyl), -NHSO₂(phenyl), and -NHSO₂(C₁-C₄ haloalkyl).

Aminocarbonyl is meant to include carbamoyl-; lower-alkyl carbamoyl-; benzylcarbamoyl-; phenylcarbamoyl-; methoxymethyl-carbamoyl-; and the like.

[0028] **Halogen or halo** refers to fluorine, chlorine, bromine or iodine.

Fluorine, chlorine and bromine are preferred. Dihaloaryl-, dihaloalkyl-, trihaloaryl etc. refer to aryl and alkyl substituted with the designated plurality of halogens (here, 2, 2 and 3, respectively), but not necessarily a plurality of the same halogen; thus 4-chloro-3-fluorophenyl is within the scope of dihaloaryl-.

[0029] **Heterocyclyl** means a cycloalkyl or aryl residue in which one to four of the carbons is replaced by a heteroatom such as oxygen, nitrogen or sulfur. Examples of heterocycles that fall within the scope of the invention include azetidinyl-, imidazolinyl-, pyrrolidinyl-, pyrazolyl-, pyrrolyl-, indolyl-, quinolinyl-, isoquinolinyl-, tetrahydroisoquinolinyl-, benzofuranyl-, benzodioxanyl-, benzodioxyl (commonly referred to as methylenedioxyphenyl-, when occurring as a substituent), tetrazolyl-, morpholinyl-, thiazolyl-, pyridinyl-, pyridazinyl-, piperidinyl-, pyrimidinyl-, thienyl-, furanyl-, oxazolyl-, oxazolinyl-, isoxazolyl-, dioxanyl-, tetrahydrofuranyl and the like. “N-heterocyclyl” refers to a nitrogen-containing heterocycle. The term heterocyclyl encompasses heteroaryl-, which is a subset of heterocyclyl-. Examples of N-heterocyclyl residues include azetidinyl-, 4-morpholinyl-, 4-thiomorpholinyl-, 1-piperidinyl-, 1-pyrrolidinyl-, 3-thiazolidinyl-, piperazinyl and 4-(3,4-dihydrobenzoxazinyl). Examples of substituted heterocyclyl include 4-methyl-1-piperazinyl and 4-benzyl-1-piperidinyl-.

[0030] **A leaving group or atom** is any group or atom that will, under the

reaction conditions, cleave from the starting material, thus promoting reaction at a specified site. Suitable examples of such groups unless otherwise specified are halogen atoms, mesyloxy, p-nitrobenzensulphonyloxy and tosyloxy groups.

[0031] **Optional or optionally** means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstances occurs and instances in which it does not. For example, "optionally substituted alkyl" includes "alkyl" and "substituted alkyl" as defined herein. It will be understood by those skilled in the art with respect to any group containing one or more substituents that such groups are not intended to introduce any substitution or substitution patterns that are sterically impractical and/or synthetically non-feasible and/or inherently unstable.

[0032] **Substituted alkoxy** refers to alkoxy wherein the alkyl constituent is substituted (i.e., -O-(substituted alkyl)). One suitable substituted alkoxy group is "polyalkoxy" or -O-(optionally substituted alkylene)-(optionally substituted alkoxy), and includes groups such as -OCH₂CH₂OCH₃, and residues of glycol ethers such as polyethyleneglycol, and -O(CH₂CH₂O)_xCH₃, where x is an integer of about 2-20, preferably about 2-10, and more preferably about 2-5. Another suitable substituted alkoxy group is hydroxyalkoxy or -OCH₂(CH₂)_yOH, where y is an integer of about 1-10, preferably about 1-4.

[0033] **Substituted-** alkyl-, aryl-, and heteroaryl- refer respectively to alkyl-, aryl-, and heteroaryl wherein one or more (up to about 5, preferably up to about 3) hydrogen atoms are replaced by a substituent independently chosen from the group: -R^a, -OR^b, -O(C₁-C₂ alkyl)O- (e.g., ethylenedioxy or methylenedioxy), -SR^b, guanidine, guanidine wherein one or more of the guanidine hydrogens are replaced with a lower-alkyl group, -NR^bR^c, halogen, cyano, nitro, -COR^b, -CO₂R^b, -CONR^bR^c, -OCOR^b, -OCO₂R^a, -OCONR^bR^c, -NR^cCOR^b, -NR^cCO₂R^a, -NR^cCONR^bR^c, -CO₂R^b, -CONR^bR^c, -NR^cCOR^b, -SOR^a, -SO₂R^a, -SO₂NR^bR^c, and -NR^cSO₂R^a,

where R^a is an optionally substituted C₁-C₆ alkyl-, aryl-, heteroaryl-, aryl-C₁-C₄ alkyl-, or heteroaryl-C₁-C₄ alkyl- group,

R^b is H or optionally substituted C₁-C₆ alkyl-, aryl-, heteroaryl-, aryl-C₁-C₄ alkyl-, or heteroaryl-C₁-C₄ alkyl- group;

R^c is hydrogen or C₁-C₄ alkyl-;

where each optionally substituted R^a group and R^b group is independently

unsubstituted or substituted with one or more substituents independently selected from C₁-C₄ alkyl-, aryl-, heteroaryl-, aryl-C₁-C₄ alkyl-, heteroaryl-C₁-C₄ alkyl-, C₁-C₄ haloalkyl-, -OC₁-C₄ alkyl-, -OC₁-C₄ alkylphenyl-, -C₁-C₄ alkyl-OH, -OC₁-C₄ haloalkyl-, halogen, -OH, -NH₂, -C₁-C₄ alkyl-NH₂, -N(C₁-C₄ alkyl)(C₁-C₄ alkyl), -NH(C₁-C₄ alkyl), -N(C₁-C₄ alkyl)(C₁-C₄ alkylphenyl), -NH(C₁-C₄ alkylphenyl), cyano, nitro, oxo (as a substituent for heteroaryl), -CO₂H, -C(O)OC₁-C₄ alkyl-, -CON(C₁-C₄ alkyl)(C₁-C₄ alkyl), -CONH(C₁-C₄ alkyl), -CONH₂, -NHC(O)(C₁-C₄ alkyl), -NHC(O)(phenyl), -N(C₁-C₄ alkyl)C(O)(C₁-C₄ alkyl), -N(C₁-C₄ alkyl)C(O)(phenyl), -C(O)C₁-C₄ alkyl-, -C(O)C₁-C₄ phenyl-, -C(O)C₁-C₄ haloalkyl-, -OC(O)C₁-C₄ alkyl-, -SO₂(C₁-C₄ alkyl), -SO₂(phenyl), -SO₂(C₁-C₄ haloalkyl), -SO₂NH₂, -SO₂NH(C₁-C₄ alkyl), -SO₂NH(phenyl), -NSO₂(C₁-C₄ alkyl), -NSO₂(phenyl), and -NSO₂(C₁-C₄ haloalkyl). In the compounds of the invention where T and/or T' are substituted lower alkylene, the term "substituted" also refers to alkylene groups where one or more (in one embodiment, 1 or 2) carbon atoms are replaced by a heteroatom independently selected from O, N or S, such as -CH₂-S-CH₂-.

[0034] **Sulfanyl** refers to the groups: -S-(optionally substituted alkyl), -S-(optionally substituted aryl), -S-(optionally substituted heteroaryl), and -S-(optionally substituted heterocyclyl).

[0035] **Sulfinyl** refers to the groups: -S(O)-H, -S(O)-(optionally substituted alkyl), -S(O)-(optionally substituted aryl), -S(O)-(optionally substituted heteroaryl), -S(O)-(optionally substituted heterocyclyl); and -S(O)-(optionally substituted amino).

[0036] **Sulfonyl** refers to the groups: -S(O₂)-H, -S(O₂)-(optionally substituted alkyl), -S(O₂)-(optionally substituted aryl), -S(O₂)-(optionally substituted heteroaryl), -S(O₂)-(optionally substituted heterocyclyl), -S(O₂)-(optionally substituted alkoxy), -S(O₂)-(optionally substituted aryloxy), -S(O₂)-(optionally substituted heteroaryloxy), -S(O₂)-(optionally substituted heterocyclyoxy); and -S(O₂)-(optionally substituted amino).

[0037] **Pharmaceutically acceptable salts** refers to those salts that retain the biological utility of the free compound and that are not biologically undesirable or unsuitable for pharmaceutical use, formed with a suitable acid or base, and includes pharmaceutically acceptable acid addition salts and base addition salts.

[0038] **Pharmaceutically acceptable acid addition salts** include those

derived from inorganic acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid and the like, and those derived from organic acids such as acetic acid, propionic acid, glycolic acid, pyruvic acid, oxalic acid, maleic acid, malonic acid, succinic acid, fumaric acid, tartaric acid, citric acid, benzoic acid, cinnamic acid, mandelic acid, methanesulfonic acid, ethanesulfonic acid, p-toluenesulfonic acid, salicylic acid and the like.

[0039] **Pharmaceutically acceptable base addition salts** include those derived from inorganic bases such as sodium, potassium, lithium, ammonium, calcium, magnesium, iron, zinc, copper, manganese, aluminum salts and the like. Particular embodiments are the ammonium, potassium, sodium, calcium, and magnesium salts. Base addition salts also include those derived from pharmaceutically acceptable organic non-toxic bases, including salts of primary, secondary, and tertiary amines, substituted amines including naturally occurring substituted amines, cyclic amines and basic ion exchange resins, such as isopropylamine, trimethylamine, diethylamine, triethylamine, tripropylamine, and ethanolamine.

[0040] **Protecting group** has the meaning conventionally associated with it in organic synthesis, i.e. a group that selectively blocks one or more reactive sites in a multifunctional compound such that a chemical reaction can be carried out selectively on another unprotected reactive site and such that the group can readily be removed after the selective reaction is complete. A variety of protecting groups are disclosed, for example, in T.H. Greene and P. G. M. Wuts, *Protective Groups in Organic Synthesis*, Third Edition, John Wiley & Sons, New York (1999), which is incorporated herein by reference in its entirety. For example, a hydroxy protected form is where at least one of the hydroxyl groups present in a compound is protected with a hydroxy protecting group. Likewise, amines and other reactive groups can similarly be protected.

[0041] **Solvate** refers to the compound formed by the interaction of a solvent and a compound of Formula I or salt thereof. Suitable solvates of the compounds of the Formula I or a salt thereof are pharmaceutically acceptable solvates including hydrates.

[0042] Many of the compounds described herein contain one or more asymmetric centers (e.g. the carbon to which R₂ and R_{2'} are attached where R₂ differs

from R₂) and can thus give rise to enantiomers, diastereomers, and other stereoisomeric forms that can be defined, in terms of absolute stereochemistry, as (R)- or (S)-. The present invention is meant to include all such possible isomers, including racemic mixtures, optically pure forms and intermediate mixtures. Optically active (R)- and (S)- isomers can be prepared using chiral synthons or chiral reagents, or resolved using conventional techniques. When the compounds described herein contain olefinic double bonds or other centers of geometric asymmetry, and unless specified otherwise, it is intended that the compounds include both E and Z geometric isomers. Likewise, all tautomeric forms and rotational isomers are also intended to be included.

[0043] When desired, the R- and S-isomers can be resolved by methods known to those skilled in the art, for example by formation of diastereoisomeric salts or complexes which can be separated, for example, by crystallization; via formation of diastereoisomeric derivatives which can be separated, for example, by crystallization, gas-liquid or liquid chromatography; selective reaction of one enantiomer with an enantiomer-specific reagent, for example enzymatic oxidation or reduction, followed by separation of the modified and unmodified enantiomers; or gas-liquid or liquid chromatography in a chiral environment, for example on a chiral support, such as silica with a bound chiral ligand or in the presence of a chiral solvent. It will be appreciated that where the desired enantiomer is converted into another chemical entity by one of the separation procedures described herein, a further step can be required to liberate the desired enantiomeric form. Alternatively, specific enantiomer can be synthesized by asymmetric synthesis using optically active reagents, substrates, catalysts or solvents, or by converting one enantiomer to the other by asymmetric transformation.

Compounds of the Present Invention

[0044] The present invention is directed to a class of novel compounds that are inhibitors of mitotic kinesins. While not intending to be bound by any theory, the present invention capitalizes on the finding that perturbation of mitotic kinesin function causes malformation or dysfunction of mitotic spindles, frequently resulting in cell cycle arrest and cell death.

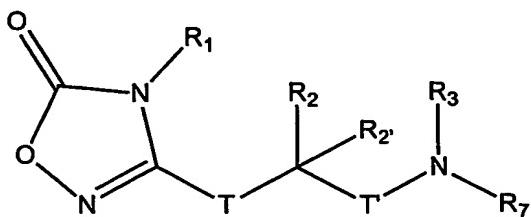
[0045] According to one embodiment of the invention, the compounds

described herein inhibit the mitotic kinesin, KSP. In another embodiment, the compounds inhibit the mitotic kinesin, KSP, as well as modulating one or more of the human mitotic kinesins selected from the group consisting of HSET (see, U.S. Patent No. 6,361,993, which is incorporated herein by reference); MCAK (see, U.S. Patent No. 6,331,424, which is incorporated herein by reference); CENP-E (see, PCT Publication No. WO99/13061 , which is incorporated herein by reference); Kif4 (see, U.S. Patent No. 6,440,684, which is incorporated herein by reference); MKLP1 (see, U.S. Patent No. 6,448,025, which is incorporated herein by reference); Kif15 (see, U.S. Patent No. 6,355,466, which is incorporated herein by reference); Kid (see, U.S. Patent No. 6,387,644, which is incorporated herein by reference); Mpp1, CMKrp, KinI-3 (see, U.S. Patent No. 6,461,855, which is incorporated herein by reference); Kip3a (see, PCT Publication No. WO 01/96593, which is incorporated herein by reference); Kip3d (see, U.S. Patent No. 6,492,151, which is incorporated herein by reference); and RabK6.

[0046] The methods of inhibiting a human kinesin comprise contacting an inhibitor of the invention with a human kinesin, particularly human KSP kinesins, including fragments and variants of KSP. The inhibition can be of the ATP hydrolysis activity of the KSP kinesin and/or the mitotic spindle formation activity, such that the mitotic spindles are disrupted. Meiotic spindles may also be disrupted.

[0047] An object of the present invention is to develop inhibitors of mitotic kinesins, in particular KSP and especially human KSP, for the treatment of disorders associated with cell proliferation. Traditionally, dramatic improvements in the treatment of cancer, one type of cellular proliferative disorder, have been associated with identification of therapeutic agents acting through novel mechanisms. Examples of this include not only the taxane class of agents that appear to act on microtubule formation, but also the camptothecin class of topoisomerase I inhibitors. The compounds, compositions and methods described herein can differ in their selectivity and are preferably used to treat diseases of cellular proliferation, including, but not limited to cancer, hyperplasias, restenosis, cardiac hypertrophy, immune disorders, fungal disorders and inflammation.

[0048] Accordingly, the present invention relates to methods employing compounds represented by Formula I:



Formula I

wherein:

T and T' are independently a covalent bond or optionally substituted lower alkylene;

R₁ is hydrogen, optionally substituted alkyl-, optionally substituted aryl-, optionally substituted aralkyl-, optionally substituted heteroaryl-, or optionally substituted heteroaralkyl-;

R₂ and R_{2'} are independently hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl; or R₂ and R_{2'} taken together form an optionally substituted 3- to 7-membered ring which optionally incorporates from one to two heteroatoms, selected from N, O, and S in the ring;

R₃ is hydrogen, optionally substituted alkyl-, optionally substituted aryl-, optionally substituted aralkyl-, optionally substituted heteroaryl-, optionally substituted heteroaralkyl-, -C(O)-R₆, or -S(O)₂-R_{6a};

R₆ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, optionally substituted heteroaralkyl, R₄O- or R₅-NH-;

R_{6a} is optionally substituted alkyl, optionally substituted aryl, optionally substituted alkylaryl, optionally substituted heteroaryl, optionally substituted alkylheteroaryl, or R₅-NH-;

R₇ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl;

or R₇ taken together with R₃, and the nitrogen to which they are bound, form an optionally substituted 5- to 12-membered nitrogen-containing heterocycle, which

optionally incorporates from one to two additional heteroatoms, chosen from N, O, and S in the heterocycle ring;

or R₇ taken together with R₂ form an optionally substituted 5- to 12-membered nitrogen-containing heterocycle, which optionally incorporates from one to two additional heteroatoms, chosen from N, O, and S in the heterocycle ring;

R₄ is optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl; and

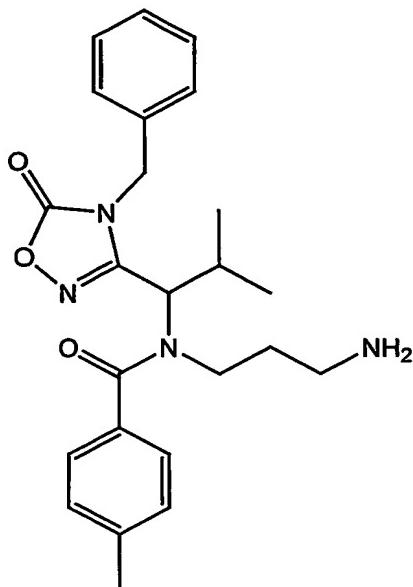
R₅ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl;

(Formula I including single stereoisomers and mixtures of stereoisomers);
a pharmaceutically acceptable salt of a compound of Formula I;
a pharmaceutically acceptable solvate of a compound of Formula I; or
a pharmaceutically acceptable solvate of a pharmaceutically acceptable salt of a compound of Formula I.

[0049] In a particular embodiment, the stereogenic center to which R₂ and R_{2'} are attached is of the R configuration.

Nomenclature

[0050] The compounds of Formula I can be named and numbered in the manner (e.g., using AutoNom version 2.1 in ChemDraw or ISIS-DRAW) described below.



i.e., the compound according to Formula I where T and T' are a covalent bond, R₁ is benzyl, R₂ is propyl (or i -propyl), R_{2'} is hydrogen; R₃ is $-\text{COR}_6$; R₇ is 3-aminopropyl; and R₆ is p-tolyl can be named N-(3-amino-propyl)-N-[1-(4-benzyl-5-oxo-4,5-dihydro-[1,2,4]oxadiazol-3-yl)-2-methyl-propyl]-4-methyl-benzamide.

Synthetic Reaction Parameters

[0051] The compounds of Formula I can be prepared by following the procedures described with reference to the Reaction Schemes below.

[0052] The optionally substituted compounds of Formula 101 and other reactants are commercially available, e.g., from Aldrich Chemical Company, Milwaukee, WI, or can be readily prepared by those skilled in the art using commonly employed synthetic methodology.

[0053] Unless specified otherwise, the terms "solvent", "inert organic solvent" or "inert solvent" mean a solvent inert under the conditions of the reaction being described in conjunction therewith [including, for example, benzene, toluene, acetonitrile, tetrahydrofuran ("THF"), dimethylformamide ("DMF"), chloroform, methylene chloride (or dichloromethane), diethyl ether, methanol, pyridine and the like]. Unless specified to the contrary, the solvents used in the reactions of the present invention are inert organic solvents.

[0054] In general, esters of carboxylic acids can be prepared by conventional

esterification procedures, for example alkyl esters can be prepared by treating the required carboxylic acid with the appropriate alkanol, generally under acidic conditions. Likewise, amides can be prepared using conventional amidation procedures, for example amides can be prepared by treating an activated carboxylic acid with the appropriate amine. Alternatively, a lower-alkyl ester such as a methyl ester of the acid can be treated with an amine to provide the required amide, optionally in presence of trimethylaluminium following the procedure described in Tetrahedron Lett. 48, 4171-4173, (1977). Carboxyl groups can be protected as alkyl esters, for example methyl esters, which esters can be prepared and removed using conventional procedures, one convenient method for converting carbomethoxy to carboxyl is to use aqueous lithium hydroxide.

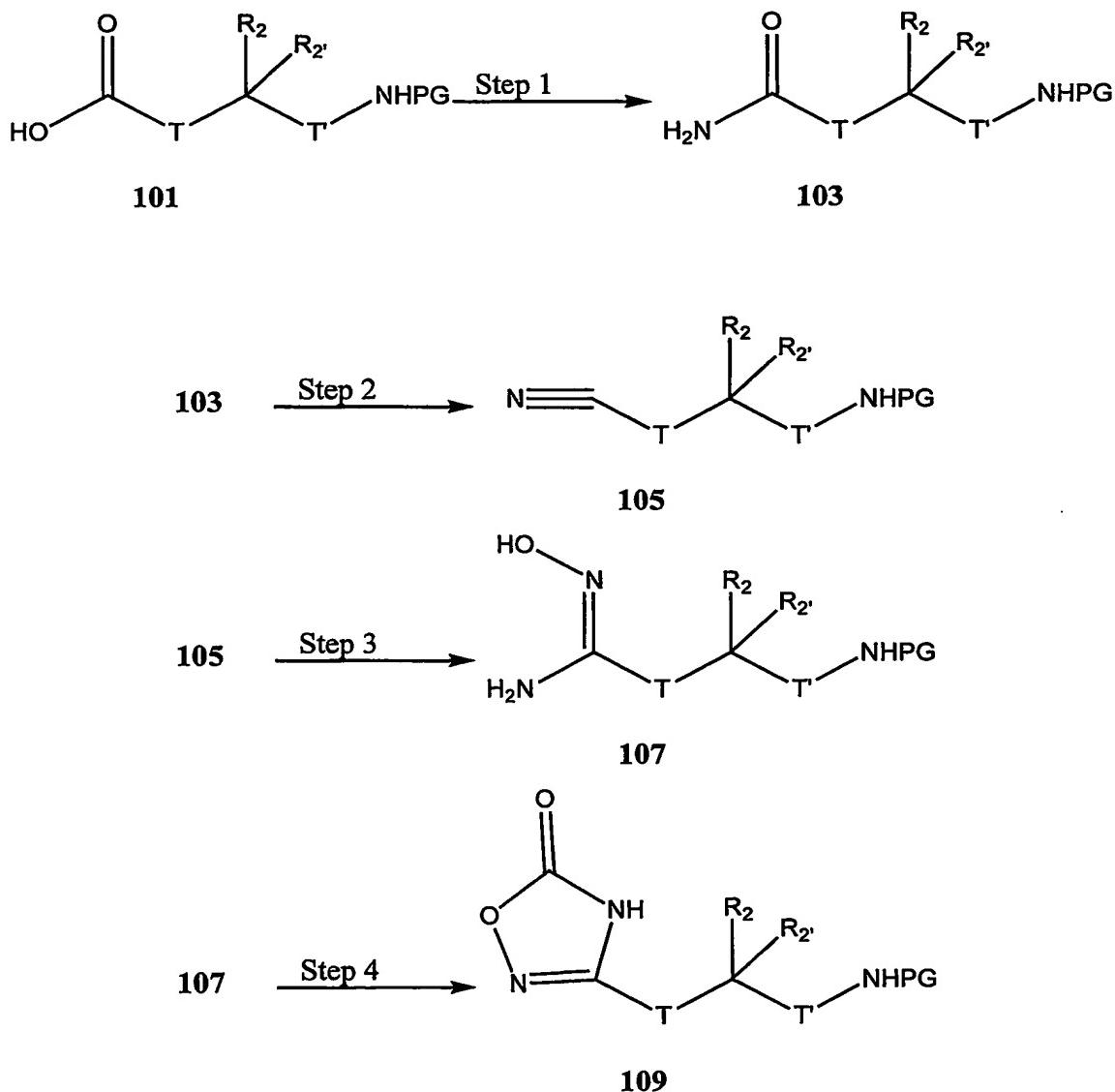
[0055] The salts and solvates of the compounds mentioned herein can as required be produced by methods conventional in the art. For example, if an inventive compound is an acid, a desired base addition salt can be prepared by treatment of the free acid with an inorganic or organic base, such as an amine (primary, secondary, or tertiary); an alkali metal or alkaline earth metal hydroxide; or the like. Illustrative examples of suitable salts include organic salts derived from amino acids such as glycine and arginine; ammonia; primary, secondary, and tertiary amines; such as ethylenediamine, and cyclic amines, such as cyclohexylamine, piperidine, morpholine, and piperazine; as well as inorganic salts derived from sodium, calcium, potassium, magnesium, manganese, iron, copper, zinc, aluminum, and lithium.

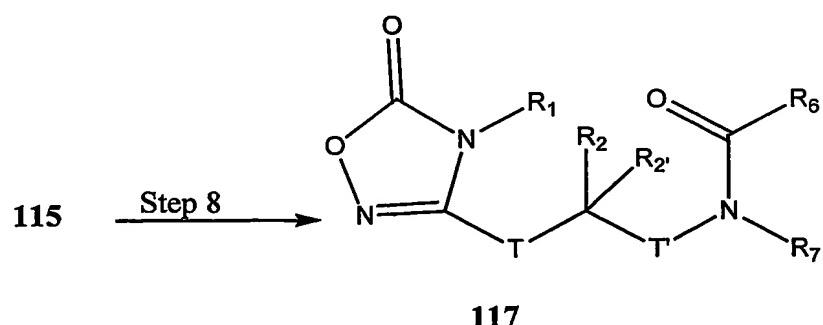
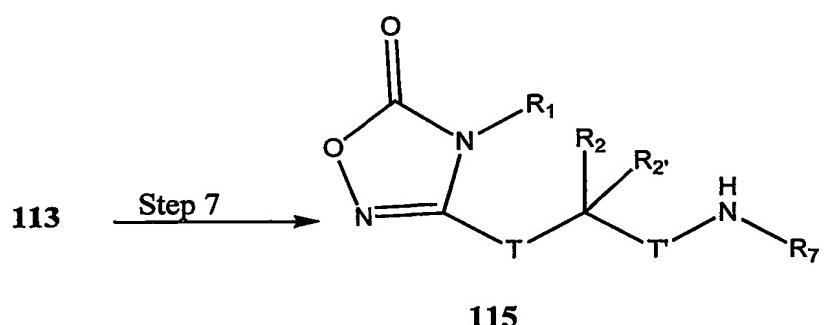
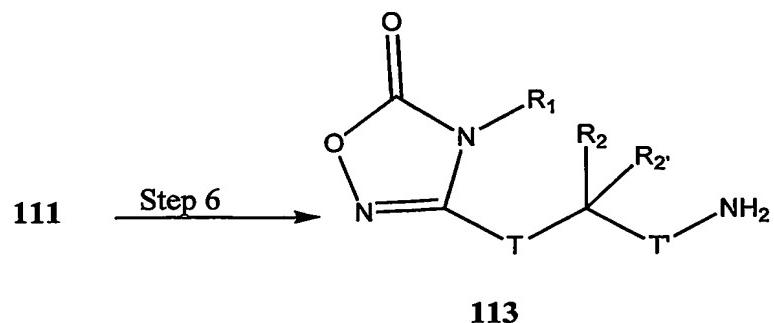
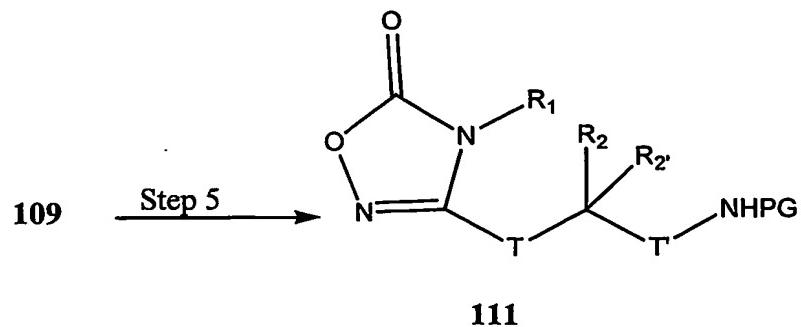
[0056] If a compound is a base, a desired acid addition salt can be prepared by any suitable method known in the art, including treatment of the free base with an inorganic acid, such as hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid, and the like, or with an organic acid, such as acetic acid, maleic acid, succinic acid, mandelic acid, fumaric acid, malonic acid, pyruvic acid, oxalic acid, glycolic acid, salicylic acid, pyranosidyl acid, such as glucuronic acid or galacturonic acid, alpha-hydroxy acid, such as citric acid or tartaric acid, amino acid, such as aspartic acid or glutamic acid, aromatic acid, such as benzoic acid or cinnamic acid, sulfonic acid, such as p-toluenesulfonic acid, methanesulfonic acid, ethanesulfonic acid, or the like.

[0057] Isolation and purification of the compounds and intermediates described herein can be effected, if desired, by any suitable separation or purification

procedure such as, for example, filtration, extraction, crystallization, column chromatography, thin-layer chromatography or thick-layer chromatography, or a combination of these procedures. Specific illustrations of suitable separation and isolation procedures can be had by reference to the examples hereinbelow. However, other equivalent separation or isolation procedures can, of course, also be used.

Reaction Scheme 1





Preparation of Compounds of Formula 103

[0058] Referring to Reaction Scheme 1, Step 1, to a solution of a compound of Formula 101, preferably where the amino protecting group is a Boc group, and *N*-methyl morpholine in an anhydrous, aprotic solvent such as anhydrous tetrahydrofuran at about 0 °C is added an excess (preferably about 1.3 equivalents) of *iso*-butyl chloroformate. The resulting mixture is stirred at room temperature for about 4 hours. The flask is then equipped with a dry-ice reflux condenser and purged continuously with gaseous ammonia for about 2 hours. The product, a compound of Formula 103, is isolated and used for the subsequent transformation without purification.

Preparation of Compounds of Formula 105

[0059] Referring to Reaction Scheme 1, Step 2, to a room temperature solution of a compound of Formula 103 in a polar, aprotic solvent such as dioxane are added an excess of pyridine and an excess of trifluoroacetic anhydride, successively. The resulting solution is stirred for about 4 hours. The product, a compound of Formula 105, is isolated and purified.

Preparation of Compounds of Formula 107

[0060] Referring to Reaction Scheme 1, Step 3, to a room temperature solution of a compound of Formula 105 in a polar, protic solvent such as methanol are added a solution of sodium methoxide (preferably, about 0.5 M) and an excess (preferably about two equivalents) of hydroxylamine hydrochloride, successively. The resulting solution is heated to about 50 °C overnight and then cooled to room temperature. The product, a compound of Formula 107, is isolated and used in the subsequent transformation without purification.

Preparation of Compounds of Formula 109

[0061] Referring to Reaction Scheme 1, Step 4, to a room temperature solution of a compound of Formula 107 in a polar, aprotic solvent such as tetrahydrofuran were added diisopropylethylamine and an excess (preferably about 1.1 equivalents) of 1,1'-carbonyldiimidazole. The resulting solution is stirred for about 4 hours. The product, a compound of Formula 109, is isolated and purified.

Preparation of Compounds of Formula 111

[0062] Referring to Reaction Scheme 1, Step 5, to a room temperature solution of a compound of Formula 109 in a polar, aprotic solvent such as *N,N*-dimethylformamide are added a base such as potassium carbonate and an excess (preferably about 2.1 equivalents) of a compound of formula R₁-X wherein X is a leaving group (preferably, a halide). The resulting suspension is stirred at about 40 °C for about 6 hours. The product, a compound of Formula 111, is isolated and purified.

Preparation of Compounds of Formula 113

[0063] Referring to Reaction Scheme 1, Step 6, the amino protecting group is then removed. When the amino protecting group, PG, is Boc, this can be accomplished by treating a solution of a compound of Formula 111 in a nonpolar, aprotic solvent such as dichloromethane at about 0 °C with trifluoroacetic acid. The resulting solution is stirred at room temperature for about 1 hour. The product, a compound of Formula 113, is isolated and used in the next step without further purification.

Preparation of Compounds of Formula 115

[0064] Referring to Reaction Scheme 1, Step 7, to a room temperature solution of a compound of Formula 501 in a nonpolar, aprotic solvent such as dichloromethane are added successively an excess (preferably about 1.2 equivalents) of sodium triacetoxyborohydride and an excess (preferably about 1.2 equivalents) of an aldehyde comprising R₇· (i.e., a compound having the formula R₇·CHO where R₇·CH₂· is equivalent to R₇ and R₇ is as described herein or is a protected precursor to such a substituent, e.g., (3-oxo-propyl)-carbamic acid *tert*-butyl ester). The resulting mixture is stirred at the same temperature under nitrogen for about 12 hours. The product, a compound of Formula 115, is isolated and purified.

Preparation of Compounds of Formula 117

[0065] Referring to Reaction Scheme 1, Step 8, to a solution of a compound of Formula 115 in a nonpolar, aprotic solvent such as dichloromethane at about 0°C are added a base such as DIEA and an excess (preferably about 1.1 equivalents) of an acid chloride of Formula R₆-(CO)-Cl. The resulting solution is stirred under nitrogen at

room temperature overnight. The product, a compound of Formula 117, is isolated and purified.

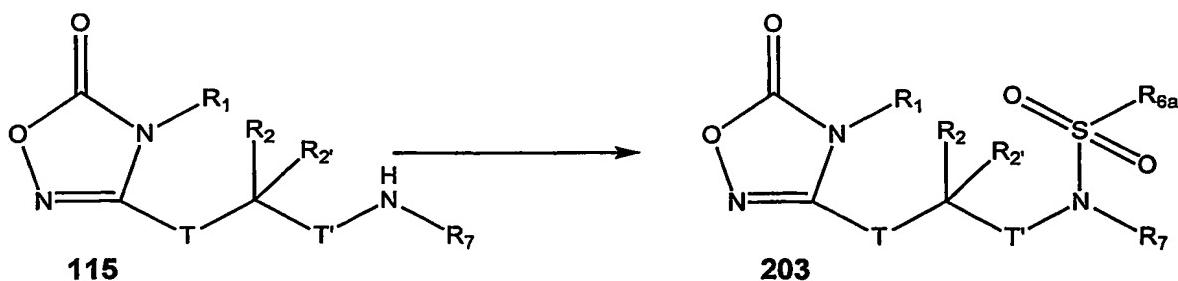
[0066] In an embodiment wherein R₇ further comprises a protected amine, the protecting group may be removed. For example, when the amino protecting group is Boc, this may be accomplished by treating a solution of a compound of Formula 117 in a nonpolar, aprotic solvent such as CH₂Cl₂ with trifluoroacetic acid. The product, the corresponding free amine, is isolated and purified.

Preparation of Optically Active Compounds

[0067] In certain compounds of the invention, a particular stereo configuration (such as the (R) isomer) may be preferred at the stereogenic center to which R² is attached. The optically active compound may be prepared directly using optically active starting materials or reagents. Alternatively, the optically active compound can be prepared from the racemic mixture by methods known in the art. For example, an amine of Formula 113 is dissolved in an inert organic solvent (such as IPA) and warmed to 60°C. In a separate vessel, a resolving agent (such as dibenzoyl-D-tartaric acid) is dissolved, preferably in the same warm solvent, and then quickly added (with agitation) to the warm amine solution. The reaction mixture is left to crystallize by cooling to room temperature over about 16 hours under continuing agitation. The desired isomer, e.g., the (R) isomer, is isolated and purified.

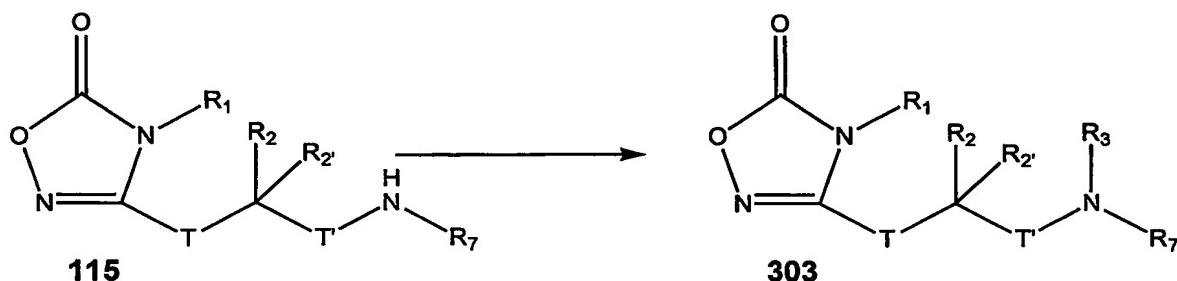
[0068] For the sake of brevity in the remaining description of the synthesis of compounds of Formula I, it should be understood that either single isomer or a mixture of isomers may be employed to give the corresponding product.

Reaction Scheme 2



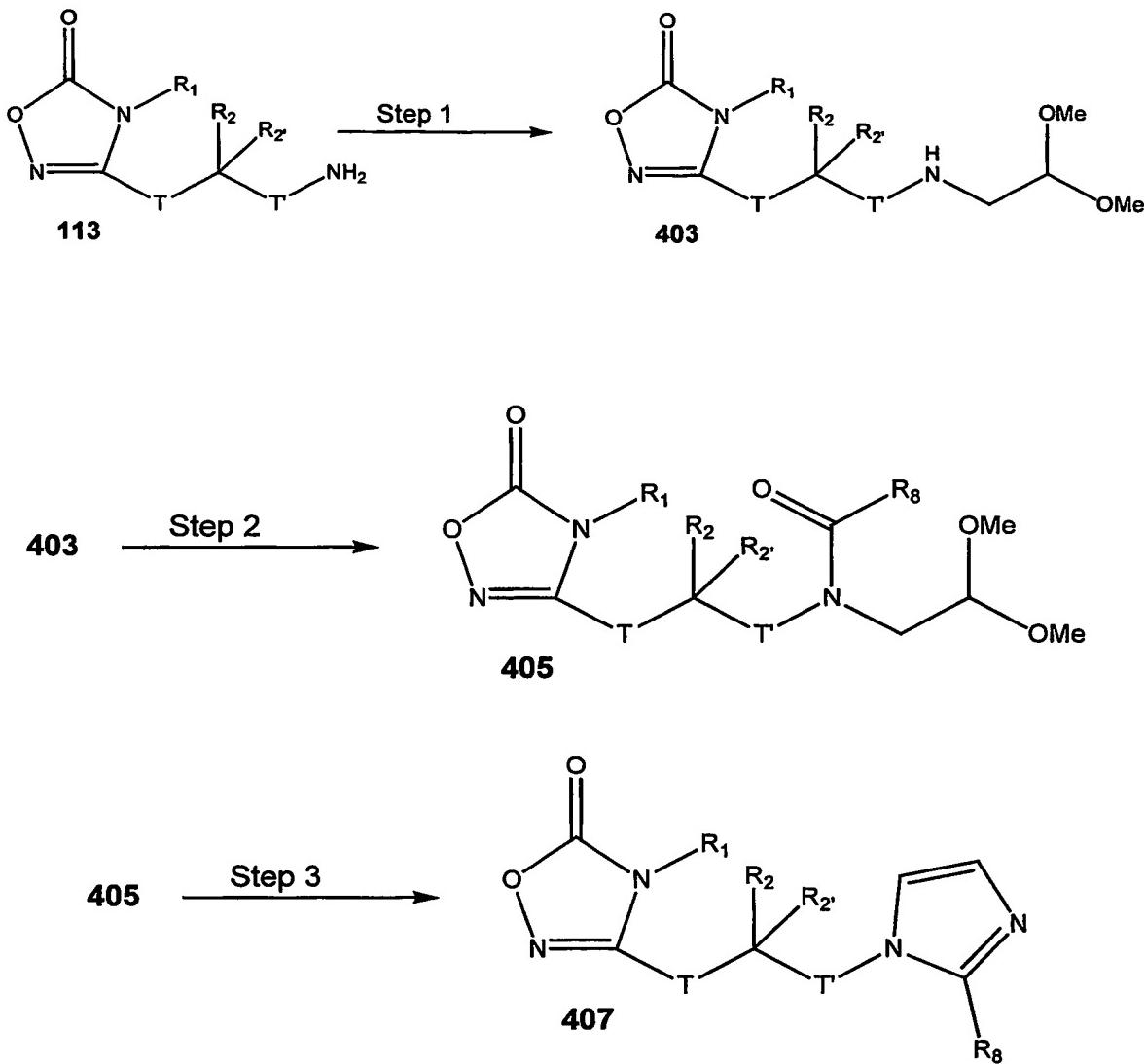
[0069] Referring to Reaction Scheme 2, to a solution of a compound of Formula 115 and an amine base such as diisopropylethylamine in a nonpolar, aprotic solvent such as dichloromethane is added a compound having the formula Cl-S(O)₂-R_{6a} or O-(S(O)₂-R_{6a})₂ where R_{6a} is as described herein. The resulting solution is stirred under nitrogen at room temperature for several hours. The product, a compound of Formula 203, is isolated and purified.

Reaction Scheme 3



[0070] Referring to Reaction Scheme 3, to a solution of a compound of Formula 115 and an amine base such as diisopropylethylamine in a nonpolar, aprotic solvent such as dichloromethane is added a compound having the formula X-R₃ where R₃ is as described herein and X is a leaving group (preferably, a halide). The resulting solution is stirred under nitrogen at room temperature or with heat for several hours. The product, a compound of Formula 303, is isolated and purified.

Reaction Scheme 4



Preparation of Formula 403

[0071] Referring to Reaction Scheme 4, Step 1, to an optionally substituted compound of Formula 113 dissolved in a polar, aprotic solvent (such as DMF) in the presence of a base (such as potassium carbonate) is added one equivalent of an optionally substituted suitably protected aldehyde wherein such aldehyde further comprises a leaving group, preferably, a halide (such as bromoacetaldehyde dimethylacetal). The solution is heated at reflux, monitoring completion of the reaction (e.g., by TLC). The reaction mixture is cooled and the corresponding, optionally substituted compound of Formula 403 is isolated and purified.

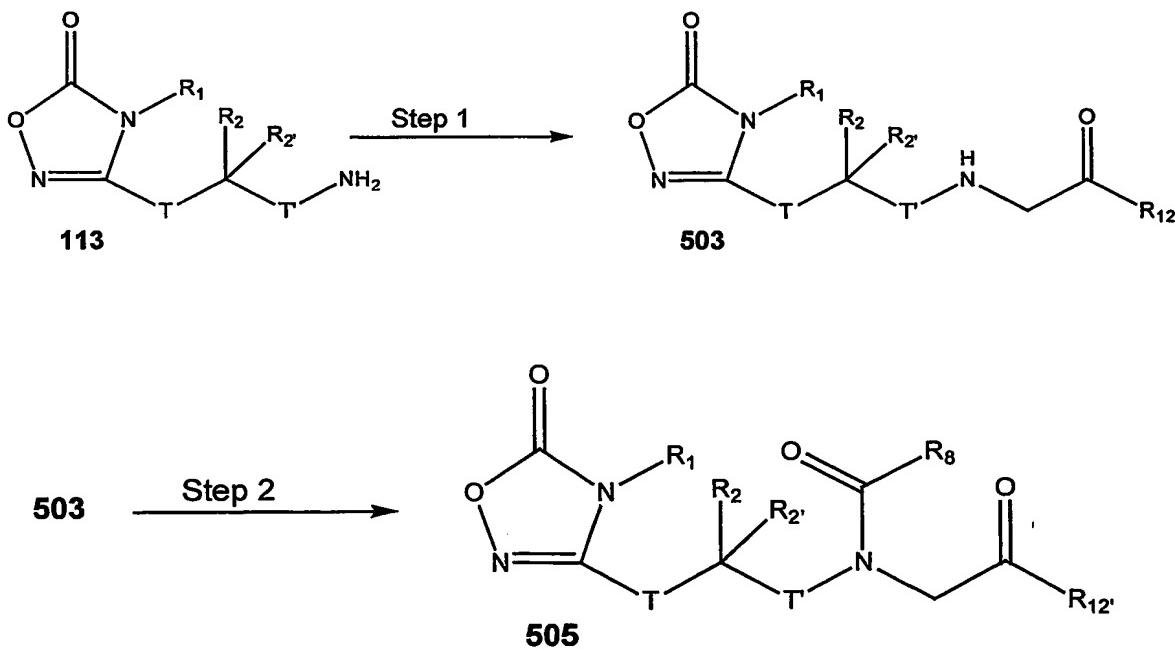
Preparation of Formula 405

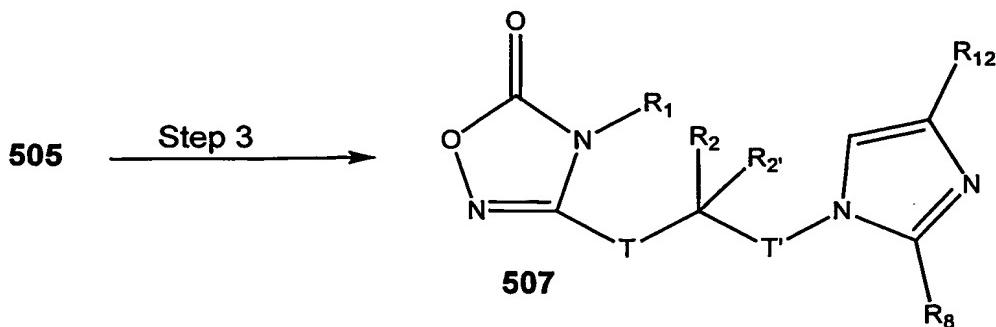
[0072] Referring to Reaction Scheme 4, Step 2, to an optionally substituted compound of Formula 403 in an inert solvent (such as dichloromethane) in the presence of about 1.5 molar equivalents of an amine base (such as triethylamine) is added about 1.5 molar equivalents of an R₈ acid chloride, such as, Cl-C(O)-R₈, where R₈ is as described below. The reaction takes place, with stirring, at room temperature over a period of 4 to 24 hours. Completion is monitored, e.g., by TLC. The corresponding compound of Formula 405 is isolated and purified.

Preparation of Formula 407

[0073] Referring to Reaction Scheme 4, Step 3, a solution of a compound of Formula 405 and an excess of ammonium acetate in acetic acid is heated at reflux for 1-4 hours. Completion is monitored, e.g., by TLC. The corresponding compound of Formula 407 is isolated and purified.

Reaction Scheme 5





Preparation of Formula 503

[0074] Referring to Reaction Scheme 5, Step 1, a suspension of a compound of Formula 113, an alpha-haloketone reagent of the Formula $R_{12'}(CO)CH_2Y$ wherein Y is a leaving group (preferably, a halide) and $R_{12'}$ is as described herein, and about an equivalent of a base, such as potassium carbonate in a polar, aprotic solvent such as DMF is stirred at room temperature. The reaction is diluted with water and the resulting solid, a compound of Formula 503, is used in the subsequent step without further purification.

Preparation of Formula 505

[0075] Referring to Reaction Scheme 5, Step 2, a solution of the compound of Formula 503, about an equivalent of an amine base, such as triethylamine and about an equivalent of an acid chloride (such as a compound of Formula R_8-COCl) in an organic solvent such as methylene chloride is stirred at room temperature for several hours. Completion is monitored, e.g., by TLC. The corresponding compound of Formula 505 is isolated and purified.

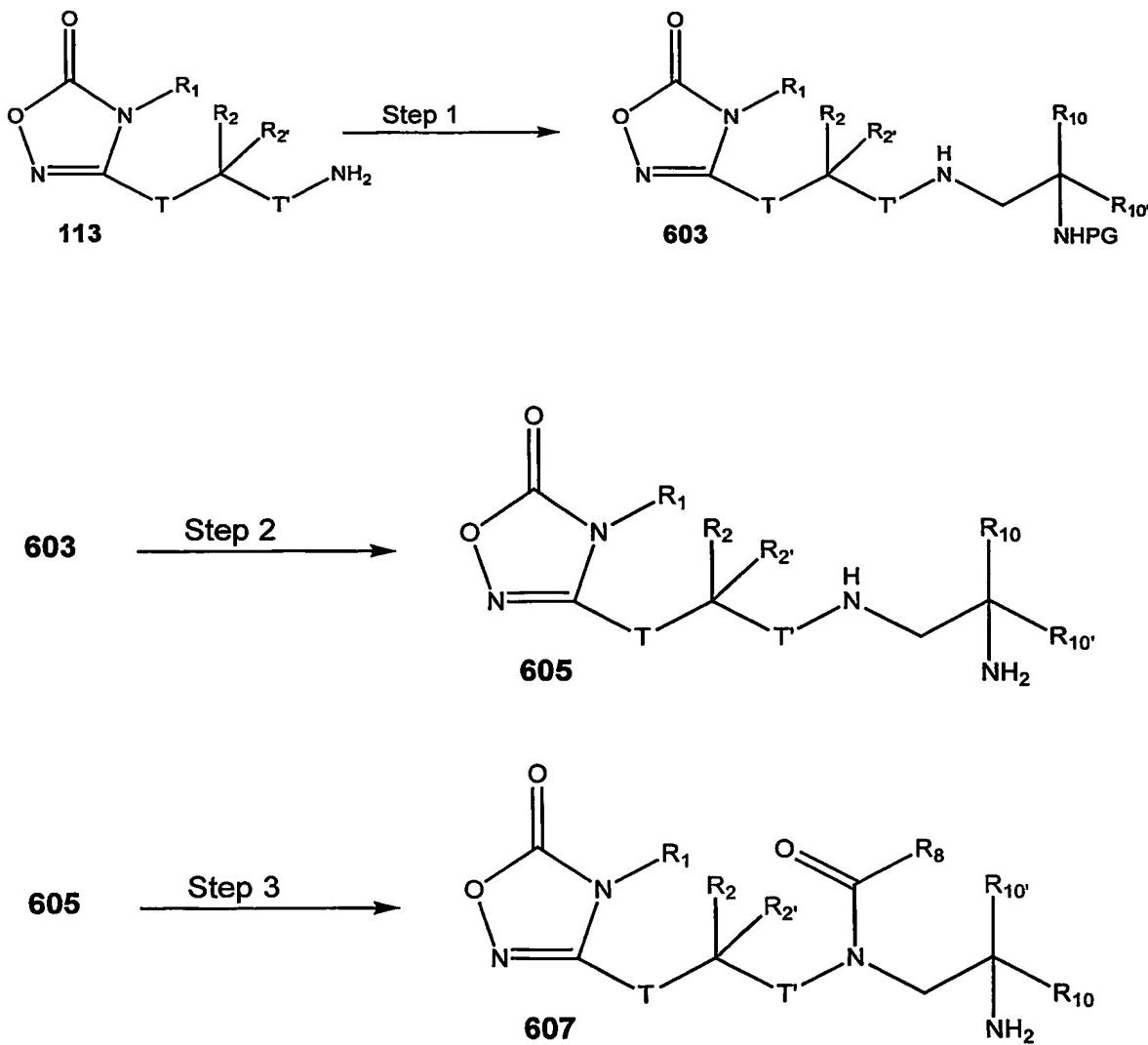
Preparation of Formula 507

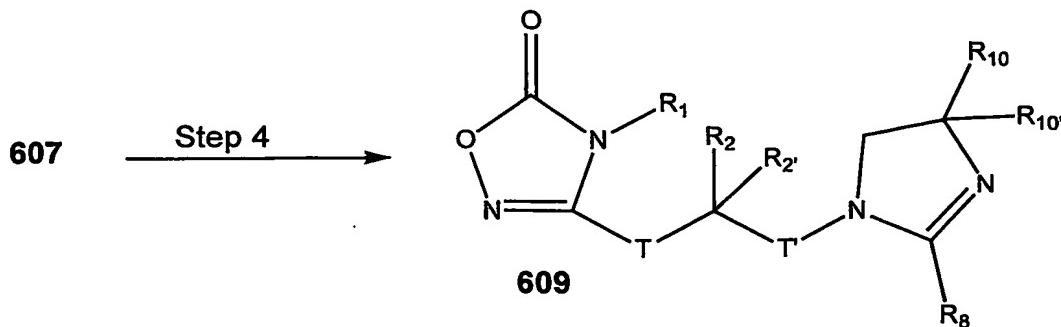
[0076] Referring to Reaction Scheme 5, Step 3, a solution of a compound of Formula 505 and an excess of ammonium acetate in acetic acid is heated at reflux using a Dean-Stark trap and condenser. Completion is monitored, e.g., by TLC. The corresponding compound of Formula 507 is isolated and purified.

[0077] In an embodiment when $R_{12'}$ comprises a protected aminoalkyl group, the amino protected group may be removed. For example, when the amino group is protected as the corresponding isoindole-1,3-dione, a solution of a compound of

Formula 507 and an excess of anhydrous hydrazine in a polar, protic solvent such as ethanol is heated at reflux. The reaction is cooled to about 5°C and any precipitate is filtered off. The filtrate is concentrated in vacuo and purified to yield the corresponding free amine.

Reaction Scheme 6





Preparation of Formula 603

[0078] Referring to Reaction Scheme 6, Step 1, reductive amination of amines of Formula 113 with an optionally substituted, aldehyde-containing carbamic acid ester gives urethane intermediates. More specifically, to a solution of a compound of Formula 113 and an equivalent of a suitably protected aldehyde (*Seki et. al. Chem. Pharm. Bull.* 1996, 44, 2061) in dichloromethane is added a slight excess of a reducing agent, such as sodium triacetoxyborohydride. The resultant cloudy mixture is maintained at ambient temperature. Completion is monitored, e.g., by TLC. The corresponding compound of Formula 603 is isolated and used in the subsequent step without purification.

Preparation of Formula 605

[0079] Referring to Reaction Scheme 6, Step 2, to a solution of a compound of Formula 603 in a nonpolar, aprotic solvent such as dichloromethane is added a strong acid such as trifluoroacetic acid. The resultant solution is maintained at ambient temperature overnight and concentrated under reduced pressure. The residue is isolated to give a compound of Formula 605 which was used in the subsequent step without purification.

Preparation of Formula 607

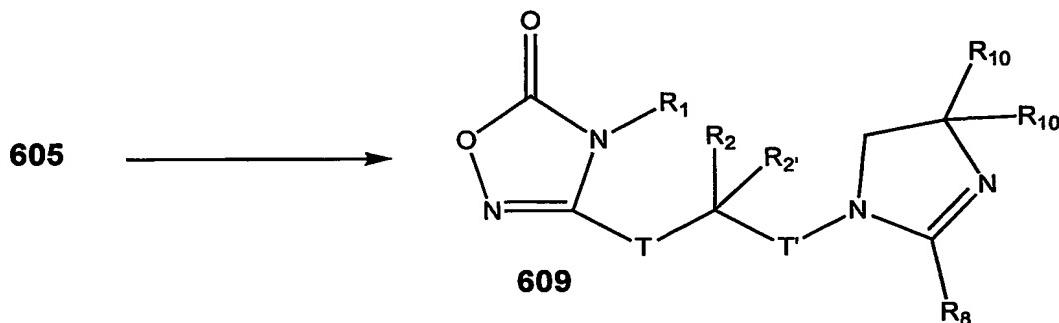
[0080] Referring to Reaction Scheme 6, Step 3, to a solution of a compound of Formula 605 in a nonpolar, aprotic solvent such as dichloromethane is added an excess, preferably about two equivalents of an amine base such as triethylamine, followed by about an equivalent or slight excess of an acid chloride of formula

R_8COCl . The resultant solution is stirred at ambient temperature for about 3 hours. Completion is monitored, e.g., by TLC. The corresponding compound of Formula 607 is isolated and purified.

Preparation of Formula 609

[0081] Referring to Reaction Scheme 6, Step 4, a solution of a compound of Formula 607 in an excess of phosphorus oxychloride is heated at reflux. After 8 hours, the reaction mixture is allowed to cool to ambient temperature and concentrated under reduced pressure. The corresponding compound of Formula 609 is isolated and purified.

Reaction Scheme 7



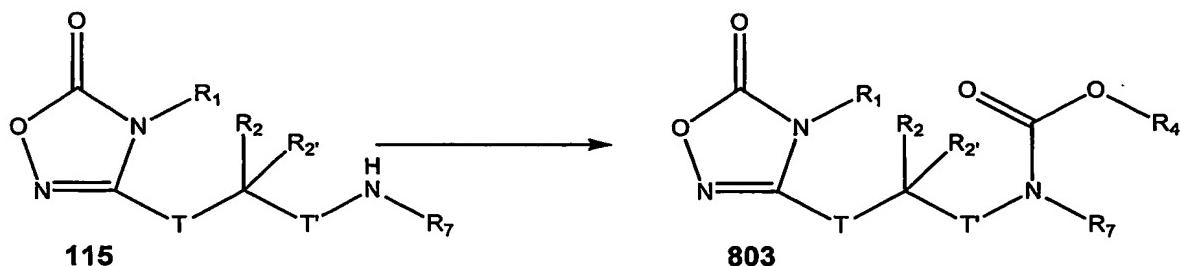
Preparation of Formula 609

[0082] As an alternative to Steps 3 and 4 of Reaction Scheme 6, acylation of primary amines of Formula 605, followed by acetic acid mediated cyclization, can proceed without isolation of the intermediate amides to provide the target compound of Formula 609. This route is shown in Reaction Scheme 7.

[0083] More specifically, to a solution of a compound of Formula 605 in a nonpolar, aprotic solvent such as dichloromethane is added an excess, preferably about two equivalents of an amine base, such as triethylamine, followed by about an equivalent of an acid chloride. The resultant solution is stirred at ambient temperature for 2 hours, then evaporated under reduced pressure. The resultant solid is treated with glacial acetic acid, then the resultant suspension is heated at reflux for about 48

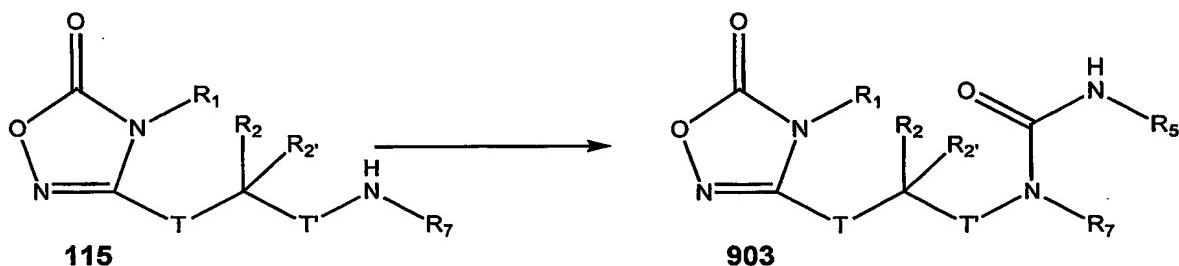
hours. The reaction is cooled to ambient temperature then evaporated under reduced pressure. The corresponding compound of Formula 609 is isolated and purified.

Reaction Scheme 8



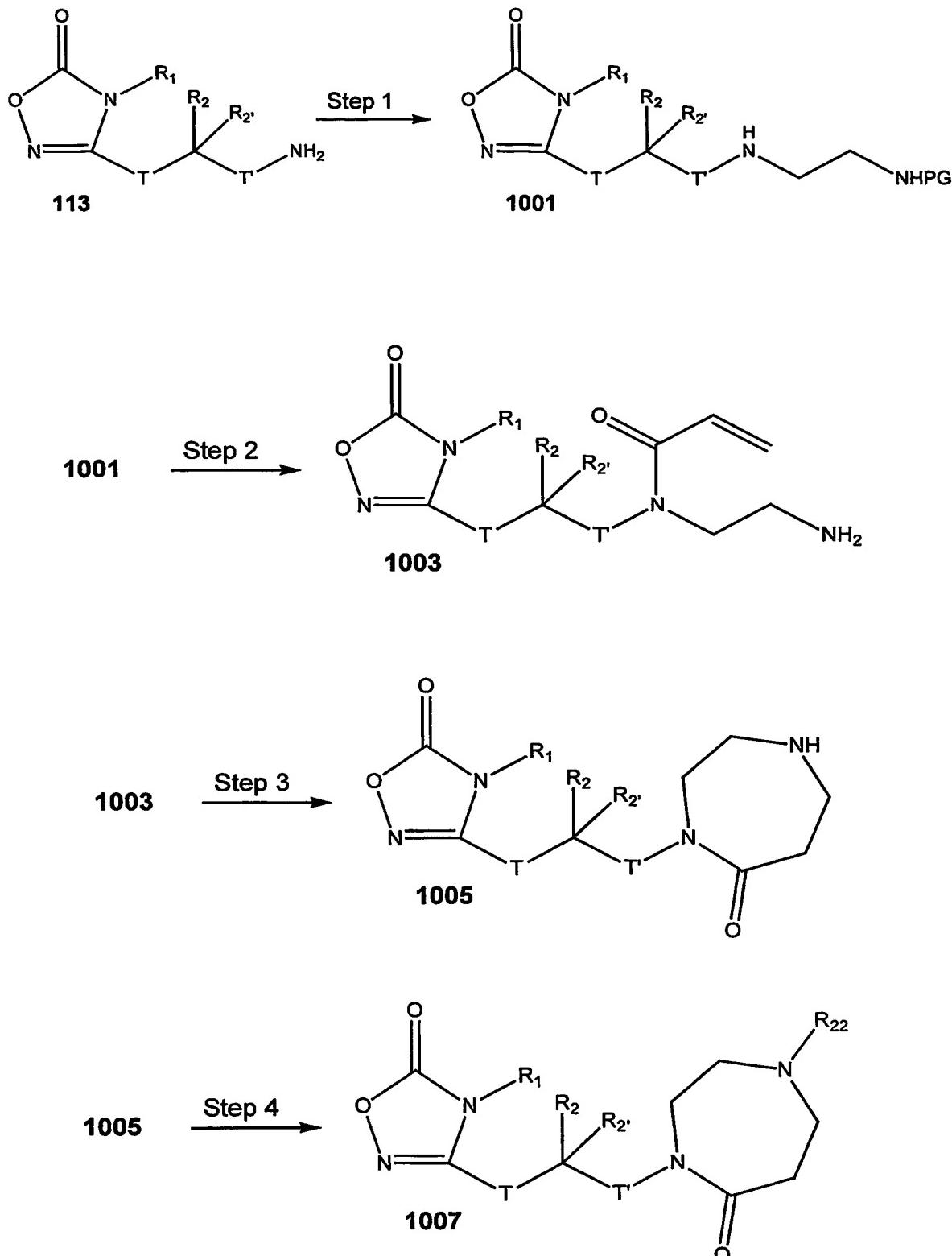
[0084] Referring to Reaction Scheme 8, a compound of Formula 115 is reacted with a slight excess of a compound of the formula $R_4O(CO)Cl$ in the presence of a base such as triethylamine in a nonpolar, aprotic solvent such as dichloromethane. The product, a compound of Formula 803 is isolated and purified.

Reaction Scheme 9



[0085] Referring to Reaction Scheme 9, a compound of Formula 115 is treated with a slight excess of an isocyanate $R_5-N=C=O$ in the presence of a base, such as triethylamine, in a nonpolar, aprotic solvent, such as dichloromethane. The product, a compound of Formula 903, is isolated and purified.

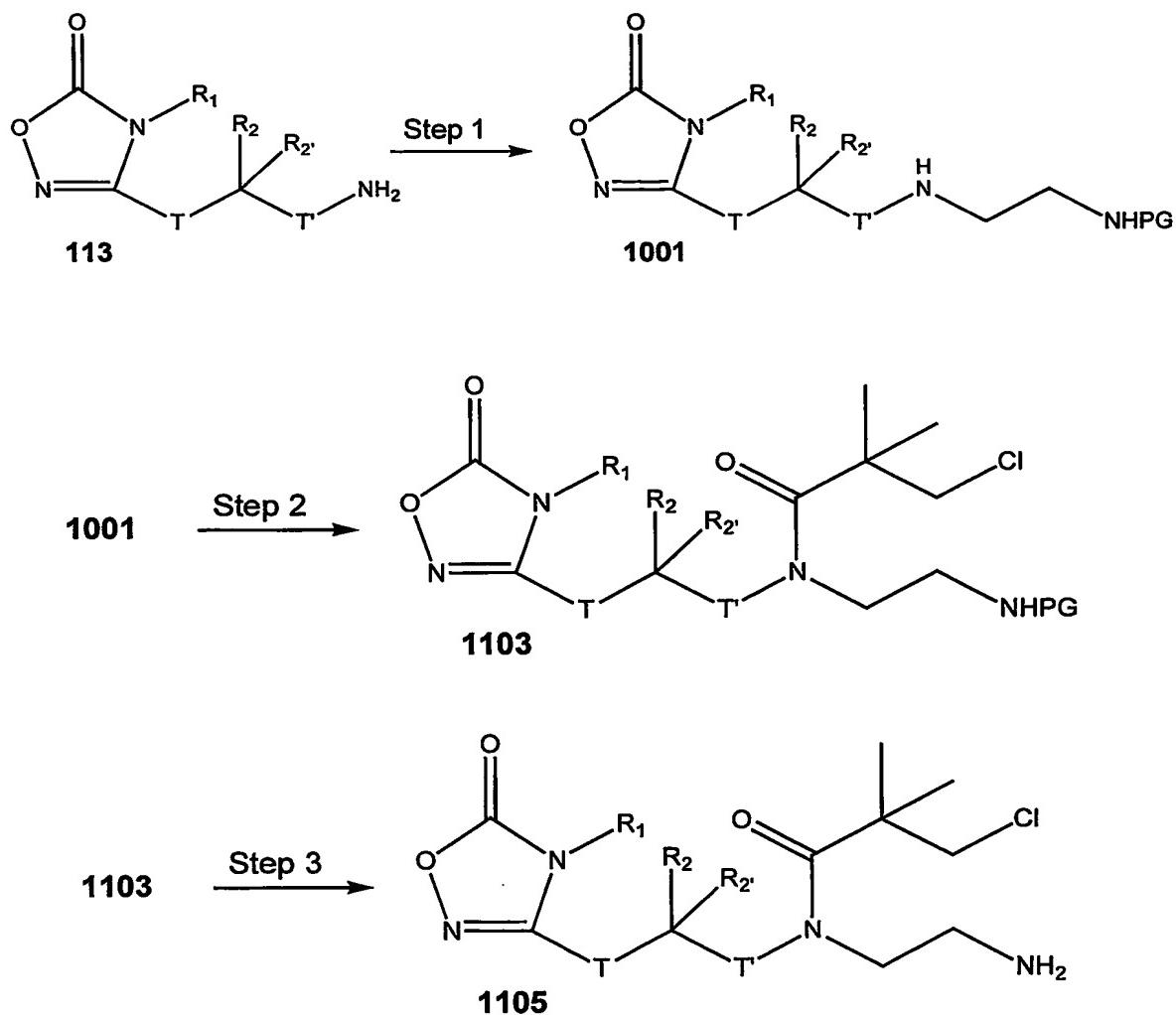
Reaction Scheme 10

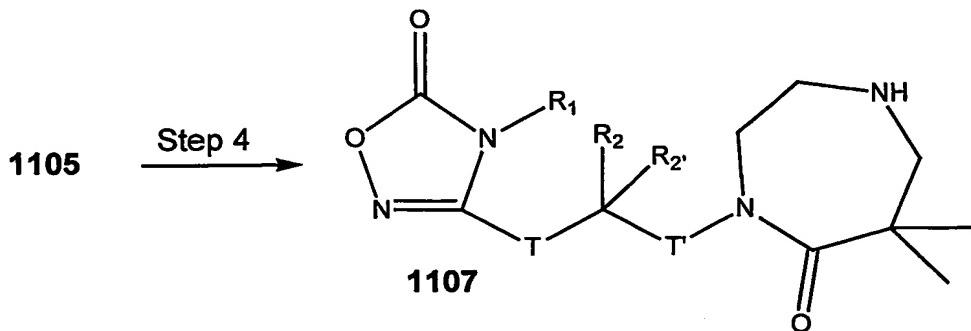


[0086] Referring to Reaction Scheme 10, reductive amination of the primary amino group in compounds of Formula 113 with (2-oxo-ethyl)-carbamic acid *tert*-

butyl ester gives the corresponding secondary amine. Acylation with acryloyl chloride followed by deprotection of the tertiary amide and base mediated cyclisation gives the desired diazepanones. If desired, further functionalization of the basic amine can be accomplished under conditions well known to those skilled in the art.

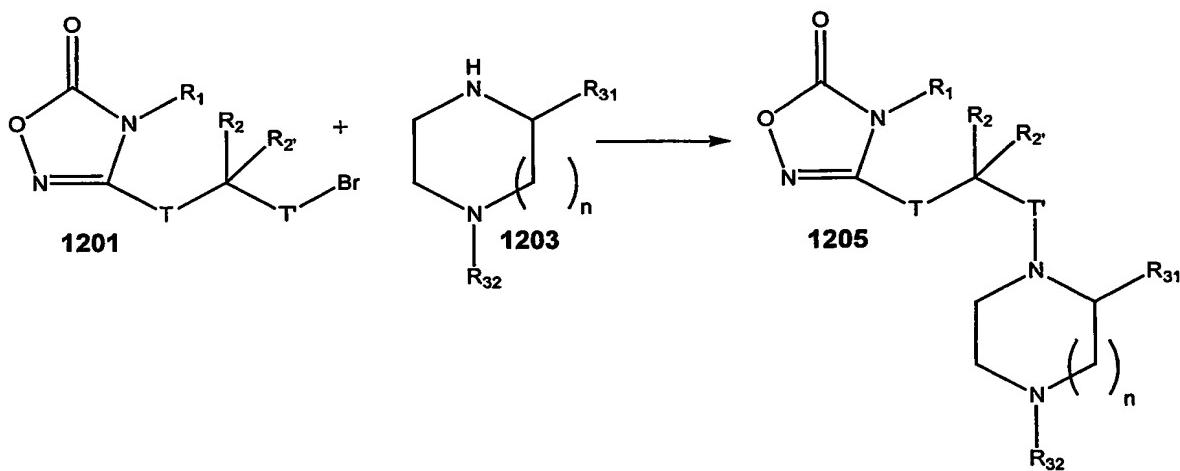
Reaction Scheme 11





[0087] Referring to Reaction Scheme 11, reductive amination of the primary amino group in compounds of Formula 113 with (2-oxo-ethyl)-carbamic acid *tert*-butyl ester gives the corresponding secondary amine. Acylation with chloropivaloyl chloride followed by deprotection of the tertiary amide and base mediated cyclisation gives the desired diazepanones. If desired, further functionalization of the basic amine can be accomplished under conditions well known to those skilled in the art.

Reaction Scheme 12



[0088] Referring to Reaction Scheme 12, a compound of Formula 1201, one-half molar equivalent of an optionally substituted piperazine or diazepam (as shown above, where R₃₂ is as described herein) and an excess of potassium carbonate are combined in an organic solvent (e.g., acetonitrile). The reaction takes place under a nitrogen atmosphere at elevated temperature (e.g., 100°C) over a period of 8 hours,

followed at a somewhat lower temperature (e.g., 60°C) for a period of 5 days. The product, a compound of Formula 1205, is isolated and purified.

[0089] Optionally, in the event that R₃₂ is an amine protecting group, such as Boc, it can be removed by for example treatment with a 95/5 mixture of TFA/water followed by stirring at room temperature for 1 hour. The product, a compound of Formula 1603 wherein R₃₂ is hydrogen, can be isolated and purified. If desired, further functionalization of the basic amine could be accomplished under conditions well known to those skilled in the art.

Particular Processes

[0090] A compound of Formula I is optionally contacted with a pharmaceutically acceptable acid or base to form the corresponding acid or base addition salt.

[0091] A pharmaceutically acceptable acid addition salt of a compound of Formula I is optionally contacted with a base to form the corresponding free base of Formula I. A pharmaceutically acceptable base addition salt of a compound of Formula I is optionally contacted with an acid to form the corresponding free acid of Formula I.

[0092] A racemic mixture of isomers of a compound of Formula I is placed on a chromatography column and separated into (R)- and (S)- enantiomers.

Compounds

T and T'

[0093] When considering the compounds of the invention, T is optionally substituted lower alkylene or is covalent bond; and T' is optionally substituted lower alkylene or is a covalent bond. In one embodiment, one of T and T' is a covalent bond and the other is optionally substituted lower alkylene (especially optionally substituted methylene). In another embodiment, both are covalent bonds.

R₁

[0094] When considering the compounds of the invention, in a particular embodiment R₁ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted aralkyl, or optionally

substituted heteroaralkyl. In a more particular embodiment R₁ is optionally substituted lower alkyl, optionally substituted aryl, or optionally substituted aralkyl (especially optionally substituted aralkyl).

[0095] In a most particular embodiment R₁ is ethyl, propyl, methoxyethyl, naphthyl, phenyl, bromophenyl, chlorophenyl, methoxyphenyl, ethoxyphenyl, tolyl, dimethylphenyl, chlorofluorophenyl, methylchlorophenyl, ethylphenyl, phenethyl, benzyl, chlorobenzyl, methylbenzyl, methoxybenzyl, cyanobenzyl, hydroxybenzyl, dichlorobenzyl, dimethoxybenzyl, naphthylmethyl, or (ethoxycarbonyl)ethyl. In a more particular embodiment, R₁ is ethyl, propyl, methoxyethyl, naphthyl, phenethyl, benzyl, chlorobenzyl, methylbenzyl, methoxybenzyl, cyanobenzyl, hydroxybenzyl, dichlorobenzyl, dimethoxybenzyl, naphthylmethyl, or (ethoxycarbonyl)ethyl.

[0096] Most particularly, R₁ is benzyl, chlorobenzyl, methylbenzyl, methoxybenzyl, cyanobenzyl, or hydroxybenzyl. Most particularly, R₁ is benzyl.

R₂

[0097] When considering the compounds of the invention and as will be appreciated by those skilled in the art, the compounds described herein possess a potentially chiral center at the carbon to which R₂ and R_{2'} are attached. The R₂ and R_{2'} groups can be the same or different; if different, the compound is chiral (i.e., has a stereogenic center). When R₂ and R_{2'} are different, in particular embodiments R_{2'} is hydrogen and R₂ is other than hydrogen. The invention contemplates the use of pure enantiomers and mixtures of enantiomers, including racemic mixtures, although the use of a substantially optically pure enantiomer will generally be preferred. The term "substantially optically pure" or "enantiomerically pure" means having at least about 95% of the described enantiomer with no single impurity greater than about 1% and particularly, at least about 97.5% enantiomeric excess. In a particular embodiment, the stereogenic center to which R₂ and R_{2'} are attached is of the R configuration.

[0098] In one embodiment, R₂ is optionally substituted C₁-C₄ alkyl, and R_{2'} is hydrogen or optionally substituted C₁-C₄ alkyl. More particularly, R_{2'} is hydrogen and R₂ is optionally substituted C₁-C₄ alkyl. In a most particular embodiment R₂ is methyl, ethyl, propyl (particularly, c-propyl or i-propyl), butyl (particularly, t-butyl), methylthioethyl, methylthiomethyl, aminobutyl, (CBZ)aminobutyl, cyclohexylmethyl, benzyloxymethyl, methylsulfinylethyl, methylsulfinylmethyl, or hydroxymethyl, and

R_2 is hydrogen. Especially preferred is when R_2 is hydrogen and R_2' is ethyl or propyl (particularly, c-propyl or i-propyl). More particularly, R_2 is i-propyl. More preferred is the embodiment wherein the stereogenic center to which R_2 and R_2' is attached is of the R configuration.

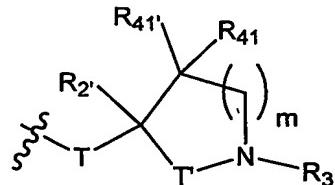
In another embodiment, both R_2 and R_2' are hydrogen.

R_2 taken together with R_7

[0099] In another embodiment, R_2 and R_7 taken together form a 5- to 12-membered ring which optionally incorporates from one to two additional heteroatoms, selected from N, O, and S in the heterocycle ring and can optionally be substituted one or more of the following groups: hydroxyl, halogen (particularly chloro and fluoro), optionally substituted C₁-C₄ alkyl- (particularly methyl-), C₁-C₄ alkoxy (particularly methoxy), cyano, amino, substituted amino, oxo, or carbamyl.

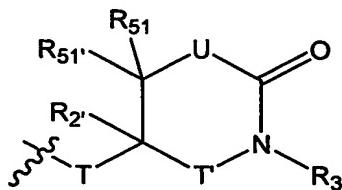
[00100] In a particular embodiment, R_2 and R_7 taken together form an optionally substituted ring of the formula:

[00101]



wherein R_{41} and R_{41}' are independently hydrogen, alkyl, aryl, aralkyl, heteroaryl, substituted alkyl, substituted aryl, substituted aralkyl, or substituted heteroaryl; m is 0, 1, 2, or 3; and T , T' , R_3 , and R_2' are as defined herein. In a more particular embodiment, R_{41} is hydrogen. In another particular embodiment, both R_{41} and R_{41}' are hydrogen. See, e.g., PCT application number PCT/US03/30788, filed September 30, 2003, which is incorporated herein by reference for all purposes.

[00102] In another embodiment, R_2 and R_7 taken together form an optionally substituted ring of the formula:



wherein R₃, R_{2'}, T, and T' are as defined herein; R₅₁ and R_{51'} are independently hydrogen, alkyl, aryl, aralkyl, heteroaryl, substituted alkyl, substituted aryl, substituted aralkyl or substituted heteroaryl; U is a covalent bond, CR'R'' or NR''''; R' and R'' are independently hydrogen, hydroxy, amino, optionally substituted aryl, optionally substituted alkylamino, optionally substituted alkyl and optionally substituted alkoxy; or R''' is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, or optionally substituted heteroaralkyl, provided that U and T' are not both covalent bonds.

[00103] In a particular embodiment, R₅₁ is hydrogen or optionally substituted lower alkyl; more particularly, R₅₁ is hydrogen. In another embodiment, R_{51'} is hydrogen or optionally substituted lower alkyl; more particularly, R_{51'} is hydrogen.

[00104] In one embodiment, U is CR'R'' where R' and/or R'' are hydrogen. In another embodiment, U is NR''' where R''' is hydrogen or optionally substituted alkyl. More particularly, R''' is hydrogen or optionally substituted amino-lower alkyl. See, e.g., USSN 10/626,012 and PCT/US03/22319, each of which is incorporated herein by reference for all purposes.

R₃

[00105] When considering the compounds of the invention, R₃ is hydrogen, optionally substituted alkyl-, optionally substituted aryl-, optionally substituted aralkyl-, optionally substituted heteroaryl-, optionally substituted heteroaralkyl-, -C(O)-R₆, or -S(O)₂-R_{6a}. In one embodiment, R₃ is optionally substituted C₁-C₁₃ alkyl (especially optionally substituted C₁-C₄ alkyl); optionally substituted aralkyl (especially optionally substituted benzyl or naphthylmethyl-); or optionally substituted heteroaralkyl. More particularly, R₃ is benzyl or benzyl substituted with one or more of the following groups: carboxy, alkoxycarbonyl cyano, halo, C₁-C₄ alkyl-, C₁-C₄ alkoxy, nitro, methylenedioxy, or trifluoromethyl. In another embodiment, and as described below, R₃ is -C(O)R₆. In yet another embodiment, and as described below

R₃ is -SO₂R_{6a}

R₆ Groups

[00106] When considering the compounds of the invention wherein R₃ is -C(O)R₆, in a particular embodiment R₆ is optionally substituted C₁-C₈ alkyl, optionally substituted aryl-C₁-C₄-alkyl-, optionally substituted heteroaryl-C₁-C₄-alkyl-, optionally substituted heteroaryl, optionally substituted aryl, R₁₁O- or R₁₂-NH-; R₁₁ is optionally substituted C₁-C₈ alkyl or optionally substituted aryl; and R₁₂ is hydrogen, optionally substituted C₁-C₈ alkyl or optionally substituted aryl.

Particular R₆ are optionally substituted C₁-C₈ alkyl, optionally substituted aryl-C₁-C₄-alkyl-, optionally substituted heteroaryl-C₁-C₄-alkyl-, optionally substituted heteroaryl, or optionally substituted aryl. In a more particular embodiment, R₆ is phenyl;

phenyl substituted with one or more of the following substituents: halo; C₁-C₄ alkyl; C₁-C₄ alkyl substituted with hydroxy (e.g., hydroxymethyl); C₁-C₄ alkoxy; C₁-C₄ alkyl substituted with C₁-C₄ alkoxy, halo, nitro, formyl, carboxy, cyano, methylenedioxy, ethylenedioxy, acyl (e.g., acetyl), -N-acyl (e.g., N-acetyl) or trifluoromethyl;

benzyl;

phenoxyethyl-;

halophenoxyethyl-;

phenylvinyl-;

heteroaryl-;

heteroaryl- substituted with C₁-C₄ alkyl or C₁-C₄ alkyl substituted with halo (e.g., CF₃);

C₁-C₄ alkyl substituted with C₁-C₄ alkoxy-; or benzyloxymethyl-.

[00107] In a most particular embodiment, R₆ is phenyl, halophenyl, dihalophenyl, cyanophenyl, halo(trifluoromethyl)phenyl, hydroxymethyl-phenyl, methoxymethylphenyl, methoxyphenyl, ethoxyphenyl, carboxyphenyl, formylphenyl, ethylphenyl, tolyl, methylenedioxyphenyl, ethylenedioxyphenyl, methoxychlorophenyl, methylhalophenyl, trifluoromethylphenyl, furanyl, C₁-C₄ alkyl substituted furanyl, trifluoromethylfuranyl, C₁-C₄ alkyl substituted trifluoromethylfuranyl, benzofuranyl, thiophenyl, C₁-C₄ alkyl substituted thiophenyl,

benzothiophenyl, benzothiadiazolyl, pyridinyl, indolyl, methylpyridinyl, trifluoromethylpyridinyl, pyrrolyl, quinolinyl, picolinyl, pyrazolyl, C₁-C₄ alkyl substituted pyrazolyl, N-methyl pyrazolyl, C₁-C₄ alkyl substituted N-methyl pyrazolyl, C₁-C₄ alkyl substituted pyrazinyl, C₁-C₄ alkyl substituted isoxazolyl, benzoisoxazolyl, morpholinomethyl, methylthiomethyl, methoxymethyl, N-methyl imidazolyl, or imidazolyl. Yet more particularly, R₆ is optionally substituted phenyl (especially, tolyl, halophenyl, methylhalophenyl, hydroxymethyl-phenyl, halo(trifluoromethyl)phenyl-, methylenedioxypyhenyl, formylphenyl or cyanophenyl).

[00108] In a more particular embodiment, when R₆ is R₅NH-, R₅ is hydrogen, C₁-C₄ alkyl; cyclohexyl; phenyl; or phenyl substituted with halo, trifluoromethyl, C₁-C₄ alkyl, C₁-C₄ alkoxy, or C₁-C₄ alkylthio-.

[00109] In a most particular embodiment, when R₆ is R₅NH-, R₅ is hydrogen, isopropyl, butyl, cyclohexyl, phenyl, bromophenyl, dichlorophenyl, methoxyphenyl, ethylphenyl, tolyl, trifluoromethylphenyl or methylthio-phenyl.

[00110] In an embodiment, wherein R₆ is R₄O-, R₄ is optionally substituted C₁-C₈ alkyl or optionally substituted aryl.

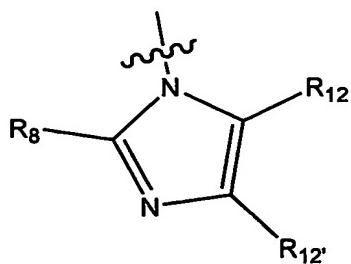
R_{6a}Groups

[00111] In one embodiment, when R₃ is -SO₂R_{6a}, R_{6a} is C₁-C₁₃ alkyl; phenyl; naphthyl; phenyl substituted with halo, lower alkyl, lower alkoxy, cyano, nitro, methylenedioxy, or trifluoromethyl; biphenyl or heteroaryl. More particularly, R_{6a} is phenyl substituted with halo, lower alkyl, lower alkoxy, cyano, nitro, methylenedioxy, or trifluoromethyl; or naphthyl.

R₃ taken together with R₇

[00112] When considering the compounds of the invention, in one embodiment, R₃ taken together with R₇, and the nitrogen to which they are bound, form an optionally substituted 5- to 12-membered nitrogen-containing heterocycle, which optionally incorporates from one to two additional heteroatoms, selected from N, O, and S in the heterocycle ring.

[00113] In a particular embodiment, R₃ taken together with R₇ and the nitrogen to which they are bound, forms an optionally substituted imidazolyl ring of the formula:



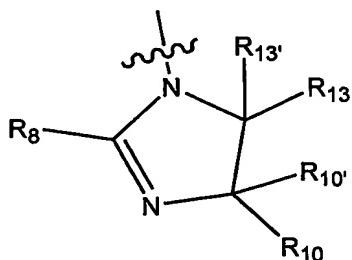
wherein

R₈ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaralkyl, optionally substituted aralkoxy, optionally substituted heteroaralkoxy, or optionally substituted heteroaryl; and

R₁₂ and R_{12'} are independently hydrogen, optionally substituted alkyl, optionally substituted aryl, or optionally substituted aralkyl.

[00114] More particularly, when R₃ taken together with R₇ and the nitrogen to which they are bound, forms an optionally substituted imidazolyl ring, R₈ is aryl (especially phenyl), substituted aryl (especially lower alkyl-, lower alkoxy-, and/or halo-substituted phenyl), aralkyl (especially benzyl or phenylvinyl), heteroaryl, substituted heteroaryl, heteroaralkyl, aralkoxy (especially phenoxy lower alkyl), heteroaralkoxy, substituted aralkyl (especially substituted benzyl or substituted styrenyl), substituted heteroaralkyl, substituted aralkoxy (especially substituted phenoxy lower alkyl), or substituted heteroaralkoxy. See, e.g., USSN 10/435,069 and PCT/US03/14787, each of which is incorporated herein by reference.

[00115] In another particular embodiment, R₃ taken together with R₇ forms an optionally substituted imidazolinyl ring of the formula:



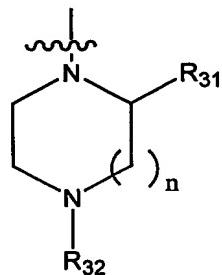
wherein,

R₈ is hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted aralkyl, optionally substituted heteroaryl, optionally substituted heteroaralkyl, optionally substituted aralkoxy, or optionally substituted heteroaralkoxy; and

R₁₀, R_{10'}, R₁₃, and R_{13'} are independently hydrogen, optionally substituted alkyl, optionally substituted aryl, or optionally substituted aralkyl.

[00116] When R₃ taken together with R₇ forms an optionally substituted imidazolinyl ring, in a particular embodiment, R₈ is aryl (especially phenyl), substituted aryl (especially lower alkyl-, lower alkoxy-, and/or halo-substituted phenyl), aralkyl (especially benzyl or phenylvinyl), heteroaryl, substituted heteroaryl, heteroaralkyl, aralkoxy (especially phenoxy lower alkyl), heteroaralkoxy, substituted aralkyl (especially substituted benzyl or substituted styrenyl), substituted heteroaralkyl, substituted aralkoxy (especially substituted phenoxy lower alkyl), or substituted heteroaralkoxy.

[00117] In another embodiment, R₃ taken together with R₇ forms an optionally substituted piperazine- or diazepam of the formula:



R₃₁ and R₃₂ are independently hydrogen, optionally substituted alkyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted aralkyl, or optionally substituted heteroaralkyl; and n is 1 or 2. More particularly, R₃₁ is aryl (especially phenyl), substituted aryl (especially lower alkyl-, lower alkoxy-, and/or halo-substituted phenyl), aralkyl (especially benzyl or phenylvinyl), heteroaralkyl,

substituted aralkyl (especially substituted benzyl or substituted phenylvinyl), or substituted heteroaralkyl; R₃₂ is hydrogen; and n is 1. See, e.g., USSN 10/644,244 and PCT/US03/26093, each of which is incorporated herein by reference.

R₇

[00118] When considering compounds of the invention, in a particular embodiment, R₇ is hydrogen, optionally substituted C₁-C₁₃ alkyl, optionally substituted aryl, optionally substituted aryl-C₁-C₄-alkyl-, optionally substituted heterocyclyl, or optionally substituted heteroaryl-C₁-C₄-alkyl- (especially hydrogen or optionally substituted C₁-C₁₃ alkyl).

[00119] More particularly, R₇ is hydrogen, C₁-C₄ alkyl; cyclohexyl; phenyl substituted with hydroxyl, C₁-C₄ alkoxy or C₁-C₄ alkyl; benzyl; or R₁₆-alkylene-, wherein R₁₆ is hydroxyl, carboxy, (C₁-C₄ alkoxy)carbonyl-, di(C₁-C₄ alkyl)amino-, (C₁-C₄ alkyl)amino-, amino, (C₁-C₄ alkoxy)carbonylamino-, C₁-C₄ alkoxy-, or optionally substituted N-heterocyclyl- (particularly azetidinyl, morpholinyl, pyridinyl, indolyl, furanyl, pyrrolidinyl, piperidinyl or imidazolyl, each of which can be optionally substituted).

[00120] In a particular embodiment, R₇ is hydrogen, methyl, ethyl, propyl, butyl, cyclohexyl, carboxyethyl, carboxymethyl, methoxyethyl, hydroxyethyl, hydroxypropyl, dimethylaminoethyl, dimethylaminopropyl, diethylaminoethyl, diethylaminopropyl, aminopropyl, methylaminopropyl, 2,2-dimethyl-3-(dimethylamino)propyl, aminoethyl, aminobutyl, aminopentyl, aminohexyl, isopropylaminopropyl, diisopropylaminoethyl, 1-methyl-4-(diethylamino)butyl, (t-Boc)aminopropyl, hydroxyphenyl, benzyl, methoxyphenyl, methylmethoxyphenyl, dimethylphenyl, tolyl, ethylphenyl, (oxopyrrolidinyl)propyl, (methoxycarbonyl)ethyl, benzylpiperidinyl, pyridinylethyl, pyridinylmethyl, morpholinylethyl, morpholinylpropyl, piperidinyl, azetidinylmethyl, azetidinylethyl, azetidinylpropyl, pyrrolidinylethyl, pyrrolidinylpropyl, piperidinylmethyl, piperidinylethyl, imidazolylpropyl, imidazolylethyl, (ethylpyrrolidinyl)methyl, (methylpyrrolidinyl)ethyl, (methylpiperidinyl)propyl, (methylpiperazinyl)propyl, furanylmethyl or indolylethyl.

[00121] In another embodiment, R₇ is R₁₆-alkylene-, wherein R₁₆ is amino, C₁-C₄ alkylamino-, di(C₁-C₄ alkyl)amino-, C₁-C₄ alkoxy-, hydroxyl, or N-

heterocyclyl. Particularly R₁₆ is amino. In a particular embodiment, the alkylene moiety of R₁₆-alkylene- has from 1 to 6 carbon atoms.

[00122] More particularly, R₇ is aminoethyl, aminopropyl, aminobutyl, aminopentyl, aminohexyl, methylaminoethyl, methylaminopropyl, methylaminobutyl, methylaminopentyl, methylaminohexyl, dimethylaminoethyl, dimethylaminopropyl, dimethylaminobutyl, dimethylaminopentyl, dimethylaminohexyl, ethylaminoethyl, ethylaminopropyl, ethylaminobutyl, ethylaminopentyl, ethylaminohexyl, diethylaminoethyl, diethylaminopropyl, diethylaminobutyl, diethylaminopentyl, or diethylaminohexyl, most particularly aminopropyl.

Salt Forms

[00123] The present invention includes pharmaceutically acceptable acid addition salts of the compounds of Formula I. Acid addition salts of the present compounds are prepared in a standard manner in a suitable solvent from the parent compound and an excess of an acid, such as hydrochloric, hydrobromic, sulfuric, phosphoric, acetic, maleic, succinic or methanesulfonic.

[00124] The salts and/or solvates of the compounds of the Formula I which are not pharmaceutically acceptable can be useful as intermediates in the preparation of pharmaceutically acceptable salts and/or solvates of compounds of Formula I or the compounds of the Formula I themselves, and as such form another aspect of the present invention.

Particular Subgenus

[00125] When considering the compounds of the invention, in a particular embodiment,

T and T' are each a covalent bond;

R₁ is benzyl, chlorobenzyl, methylbenzyl, methoxybenzyl, cyanobenzyl, or hydroxybenzyl (especially, benzyl);

R₂' is hydrogen;

R₂ is optionally substituted C₁-C₄ alkyl (especially wherein the stereogenic center to which R₂ and R₂' is attached is of the R configuration);

R₃ is -C(O)R₆;

R₆ is optionally substituted phenyl (especially, tolyl, halophenyl,

methylhalophenyl, hydroxymethyl-phenyl, halo(trifluoromethyl)phenyl-, methylenedioxyphenyl, formylphenyl or cyanophenyl);

R₇ is R₁₆-alkylene-; and

R₁₆ is amino, C₁-C₄ alkylamino-, di(C₁-C₄ alkyl)amino-, C₁-C₄ alkoxy-, hydroxyl, or N-heterocyclyl.

[00126] When considering the compounds of the invention, in a particular embodiment,

T and T' are each a covalent bond;

R₁ is benzyl, chlorobenzyl, methylbenzyl, methoxybenzyl, cyanobenzyl, or hydroxybenzyl (especially, benzyl);

R₂ is hydrogen;

R₂ is optionally substituted C₁-C₄ alkyl (especially wherein the stereogenic center to which R₂ and R₂' is attached is of the R configuration); and

R₇ taken together with R₃, and the nitrogen to which they are bound, form an optionally substituted 5- to 12-membered nitrogen-containing heterocycle, which optionally incorporates from one to two additional heteroatoms, chosen from N, O, and S in the heterocycle ring.

[00127] A particularly preferred compound is N-(3-amino-propyl)-N-[1-(4-benzyl-5-oxo-4,5-dihydro-[1,2,4]oxadiazol-3-yl)-2-methyl-propyl]-4-methylbenzamide.

Utility, Testing and Administration

General Utility

[00128] Once made, the compounds of the invention find use in at least one of a variety of applications involving alteration of mitosis. As will be appreciated by those skilled in the art, mitosis can be altered in a variety of ways; that is, one can affect mitosis either by increasing or decreasing the activity of a component in the mitotic pathway. Stated differently, mitosis can be affected (e.g., disrupted) by disturbing equilibrium, either by inhibiting or activating certain components. Similar approaches can be used to alter meiosis.

[00129] In a particular embodiment, the compounds of the invention are used to inhibit mitotic spindle formation, thus causing prolonged cell cycle arrest in mitosis. By "inhibit" in this context is meant decreasing or interfering with mitotic spindle

formation or causing mitotic spindle dysfunction. By "mitotic spindle formation" herein is meant organization of microtubules into bipolar structures by mitotic kinesins. By "mitotic spindle dysfunction" herein is meant mitotic arrest and monopolar spindle formation.

[00130] The compounds of the invention are useful to bind to, and/or inhibit the activity of, a mitotic kinesin, KSP. In one embodiment, the KSP is human KSP, although the compounds can be used to bind to or inhibit the activity of KSP kinesins from other organisms. In this context, "inhibit" means either increasing or decreasing spindle pole separation, causing malformation, i.e., splaying, of mitotic spindle poles, or otherwise causing morphological perturbation of the mitotic spindle. Also included within the definition of KSP for these purposes are variants and/or fragments of KSP. See U.S. Patent 6,437,115, hereby incorporated by reference in its entirety. The compounds of the invention have been shown to have specificity for KSP. However, the present invention includes the use of the compounds to bind to or modulate other mitotic kinesins.

[00131] The compounds of the invention are used to treat cellular proliferation diseases. Such disease states which can be treated by the compounds, compositions and methods provided herein include, but are not limited to, cancer (further discussed below), autoimmune disease, fungal disorders, arthritis, graft rejection, inflammatory bowel disease, cellular proliferation induced after medical procedures, including, but not limited to, surgery, angioplasty, and the like. Treatment includes inhibiting cellular proliferation. It is appreciated that in some cases the cells may not be in an abnormal state and still require treatment. Thus, in one embodiment, the invention herein includes application to cells or individuals afflicted or subject to impending affliction with any one of these disorders or states.

[00132] The compounds, pharmaceutical formulations and methods provided herein are particularly deemed useful for the treatment of cancer including solid tumors such as skin, breast, brain, cervical carcinomas, testicular carcinomas, etc. More particularly, cancers that can be treated include, but are not limited to:

- Cardiac: sarcoma (angiosarcoma, fibrosarcoma, rhabdomyosarcoma, liposarcoma), myxoma, rhabdomyoma, fibroma, lipoma and teratoma;
- Lung: bronchogenic carcinoma (squamous cell, undifferentiated small cell, undifferentiated large cell, adenocarcinoma), alveolar (bronchiolar) carcinoma,

- bronchial adenoma, sarcoma, lymphoma, chondromatous hamartoma, mesothelioma;
- Gastrointestinal: esophagus (squamous cell carcinoma, adenocarcinoma, leiomyosarcoma, lymphoma), stomach (carcinoma, lymphoma, leiomyosarcoma), pancreas (ductal adenocarcinoma, insulinoma, glucagonoma, gastrinoma, carcinoid tumors, vipoma), small bowel (adenocarcinoma, lymphoma, carcinoid tumors, Karposi's sarcoma, leiomyoma, hemangioma, lipoma, neurofibroma, fibroma), large bowel (adenocarcinoma, tubular adenoma, villous adenoma, hamartoma, leiomyoma);
 - Genitourinary tract: kidney (adenocarcinoma, Wilm's tumor [nephroblastoma], lymphoma, leukemia), bladder and urethra (squamous cell carcinoma, transitional cell carcinoma, adenocarcinoma), prostate (adenocarcinoma, sarcoma), testis (seminoma, teratoma, embryonal carcinoma, teratocarcinoma, choriocarcinoma, sarcoma, interstitial cell carcinoma, fibroma, fibroadenoma, adenomatoid tumors, lipoma);
 - Liver: hepatoma (hepatocellular carcinoma), cholangiocarcinoma, hepatoblastoma, angiosarcoma, hepatocellular adenoma, hemangioma;
 - Bone: osteogenic sarcoma (osteosarcoma), fibrosarcoma, malignant fibrous histiocytoma, chondrosarcoma, Ewing's sarcoma, malignant lymphoma (reticulum cell sarcoma), multiple myeloma, malignant giant cell tumor chordoma, osteochronfroma (osteocartilaginous exostoses), benign chondroma, chondroblastoma, chondromyxofibroma, osteoid osteoma and giant cell tumors;
 - Nervous system: skull (osteoma, hemangioma, granuloma, xanthoma, osteitis deformans), meninges (meningioma, meningiosarcoma, gliomatosis), brain (astrocytoma, medulloblastoma, glioma, ependymoma, germinoma [pinealoma], glioblastoma multiform, oligodendrogioma, schwannoma, retinoblastoma, congenital tumors), spinal cord neurofibroma, meningioma, glioma, sarcoma);
 - Gynecological: uterus (endometrial carcinoma), cervix (cervical carcinoma, pre-tumor cervical dysplasia), ovaries (ovarian carcinoma [serous cystadenocarcinoma, mucinous cystadenocarcinoma, unclassified carcinoma], granulosa-thecal cell tumors, Sertoli-Leydig cell tumors, dysgerminoma, malignant teratoma), vulva (squamous cell carcinoma, intraepithelial carcinoma,

- adenocarcinoma, fibrosarcoma, melanoma), vagina (clear cell carcinoma, squamous cell carcinoma, botryoid sarcoma [embryonal rhabdomyosarcoma], fallopian tubes (carcinoma);
- Hematologic: blood (myeloid leukemia [acute and chronic], acute lymphoblastic leukemia, chronic lymphocytic leukemia, myeloproliferative diseases, multiple myeloma, myelodysplastic syndrome), Hodgkin's disease, non-Hodgkin's lymphoma [malignant lymphoma];
 - Skin: malignant melanoma, basal cell carcinoma, squamous cell carcinoma, Karposi's sarcoma, moles dysplastic nevi, lipoma, angioma, dermatofibroma, keloids, psoriasis; and
 - Adrenal glands: neuroblastoma.

As used herein, treatment of cancer includes treatment of cancerous cells, including cells afflicted by any one of the above-identified conditions. Thus, the term "cancerous cell" as provided herein, includes a cell afflicted by any one of the above identified conditions.

[00133] Another useful aspect of the invention is a kit having a compound, salt or solvate of Formula I and a package insert or other labeling including directions treating a cellular proliferative disease by administering an effective amount of the compound, salt or solvate. The compound, salt or solvate of Formula I in the kits of the invention is particularly provided as one or more doses for a course of treatment for a cellular proliferative disease, each dose being a pharmaceutical formulation including a pharmaceutical excipient and a compound, salt or solvate of Formula I.

Testing

[00134] For assay of KSP-modulating activity, generally either KSP or a compound according to the invention is non-diffusably bound to an insoluble support having isolated sample receiving areas (e.g., a microtiter plate, an array, etc.). The insoluble support can be made of any composition to which the sample can be bound, is readily separated from soluble material, and is otherwise compatible with the overall method of screening. The surface of such supports can be solid or porous and of any convenient shape. Examples of suitable insoluble supports include microtiter plates, arrays, membranes and beads. These are typically made of glass, plastic (e.g., polystyrene), polysaccharides, nylon or nitrocellulose, Teflon™, etc. Microtiter plates and arrays are especially convenient because a large number of assays can be carried

out simultaneously, using small amounts of reagents and samples. The particular manner of binding of the sample is not crucial so long as it is compatible with the reagents and overall methods of the invention, maintains the activity of the sample and is nondiffusible. Particular methods of binding include the use of antibodies (which do not sterically block either the ligand binding site or activation sequence when the protein is bound to the support), direct binding to "sticky" or ionic supports, chemical crosslinking, the synthesis of the protein or agent on the surface, etc.

Following binding of the sample, excess unbound material is removed by washing. The sample receiving areas can then be blocked through incubation with bovine serum albumin (BSA), casein or other innocuous protein or other moiety.

[00135] The compounds of the invention can be used on their own to inhibit the activity of a mitotic kinesin, particularly KSP. In one embodiment, a compound of the invention is combined with KSP and the activity of KSP is assayed. Kinesin (including KSP) activity is known in the art and includes one or more kinesin activities. Kinesin activities include the ability to affect ATP hydrolysis; microtubule binding; gliding and polymerization/depolymerization (effects on microtubule dynamics); binding to other proteins of the spindle; binding to proteins involved in cell-cycle control; serving as a substrate to other enzymes, such as kinases or proteases; and specific kinesin cellular activities such as spindle pole separation.

[00136] Methods of performing motility assays are well known to those of skill in the art. (See e.g., Hall, et al. (1996), Biophys. J., 71: 3467-3476, Turner et al., 1996, Anal Biochem. 242 (1):20-5; Gittes et al., 1996, Biophys. J. 70(1): 418-29; Shirakawa et al., 1995, J. Exp. Biol. 198: 1809-15; Winkelmann et al., 1995, Biophys. J. 68: 2444-53; Winkelmann et al., 1995, Biophys. J. 68: 72S.)

[00137] Methods known in the art for determining ATPase hydrolysis activity also can be used. Suitably, solution based assays are utilized. U.S. Patent 6,410,254, hereby incorporated by reference in its entirety, describes such assays. Alternatively, conventional methods are used. For example, P_i release from kinesin can be quantified. In one embodiment, the ATPase hydrolysis activity assay utilizes 0.3 M PCA (perchloric acid) and malachite green reagent (8.27 mM sodium molybdate II, 0.33 mM malachite green oxalate, and 0.8 mM Triton X-100). To perform the assay, 10 µL of the reaction mixture is quenched in 90 µL of cold 0.3 M PCA. Phosphate standards are used so data can be converted to mM inorganic phosphate released.

When all reactions and standards have been quenched in PCA, 100 μ L of malachite green reagent is added to the relevant wells in e.g., a microtiter plate. The mixture is developed for 10-15 minutes and the plate is read at an absorbance of 650 nm. If phosphate standards were used, absorbance readings can be converted to mM P_i and plotted over time. Additionally, ATPase assays known in the art include the luciferase assay.

[00138] ATPase activity of kinesin motor domains also can be used to monitor the effects of agents and are well known to those skilled in the art. In one embodiment ATPase assays of kinesin are performed in the absence of microtubules. In another embodiment, the ATPase assays are performed in the presence of microtubules. Different types of agents can be detected in the above assays. In a one embodiment, the effect of an agent is independent of the concentration of microtubules and ATP. In another embodiment, the effect of the agents on kinesin ATPase can be decreased by increasing the concentrations of ATP, microtubules or both. In yet another embodiment, the effect of the agent is increased by increasing concentrations of ATP, microtubules or both.

[00139] Compounds that inhibit the biochemical activity of KSP in vitro can then be screened in vivo. In vivo screening methods include assays of cell cycle distribution, cell viability, or the presence, morphology, activity, distribution, or number of mitotic spindles. Methods for monitoring cell cycle distribution of a cell population, for example, by flow cytometry, are well known to those skilled in the art, as are methods for determining cell viability. See for example, U.S. Patent 6,437,115, hereby incorporated by reference in its entirety. Microscopic methods for monitoring spindle formation and malformation are well known to those of skill in the art (see, e.g., Whitehead and Rattner (1998), J. Cell Sci. 111:2551-61; Galgio et al, (1996) J. Cell Biol., 135:399-414), each incorporated herein by reference in its entirety.

[00140] The compounds of the invention inhibit the KSP kinesin. One measure of inhibition is IC₅₀, defined as the concentration of the compound at which the activity of KSP is decreased by fifty percent relative to a control. Preferred compounds have IC₅₀'s of less than about 1 mM, with preferred embodiments having IC₅₀'s of less than about 100 μ M, with more preferred embodiments having IC₅₀'s of less than about 10 μ M, with particularly preferred embodiments having IC₅₀'s of less

than about 1 μM , and especially preferred embodiments having IC_{50} 's of less than about 100 nM, and with the most preferred embodiments having IC_{50} 's of less than about 10 nM. Measurement of IC_{50} is done using an ATPase assay such as described herein.

[00141] Another measure of inhibition is K_i . For compounds with IC_{50} 's less than 1 μM , the K_i or K_d is defined as the dissociation rate constant for the interaction of the compounds described herein with KSP. Preferred compounds have K_i 's of less than about 100 μM , with preferred embodiments having K_i 's of less than about 10 μM , and particularly preferred embodiments having K_i 's of less than about 1 μM and especially preferred embodiments having K_i 's of less than about 100 nM, and with the most preferred embodiments having K_i 's of less than about 10 nM.

[00142] The K_i for a compound is determined from the IC_{50} based on three assumptions and the Michaelis-Menten equation. First, only one compound molecule binds to the enzyme and there is no cooperativity. Second, the concentrations of active enzyme and the compound tested are known (i.e., there are no significant amounts of impurities or inactive forms in the preparations). Third, the enzymatic rate of the enzyme-inhibitor complex is zero. The rate (i.e., compound concentration) data are fitted to the equation:

$$V = V_{\max} E_0 \left[1 - \frac{(E_0 + I_0 + K_d) - \sqrt{(E_0 + I_0 + K_d)^2 - 4 E_0 I_0}}{2E_0} \right]$$

where V is the observed rate, V_{\max} is the rate of the free enzyme, I_0 is the inhibitor concentration, E_0 is the enzyme concentration, and K_d is the dissociation constant of the enzyme-inhibitor complex.

[00143] Another measure of inhibition is GI_{50} , defined as the concentration of the compound that results in a decrease in the rate of cell growth by fifty percent. Preferred compounds have GI_{50} 's of less than about 1 mM; those having a GI_{50} of less than about 20 μM are more preferred; those having a GI_{50} of less than about 10 μM more so; those having a GI_{50} of less than about 1 μM more so; those having a GI_{50} of less than about 100 nM more so; and those having a GI_{50} of less than about 10 nM even more so. Measurement of GI_{50} is done using a cell proliferation assay such as described herein. Compounds of this class were found to inhibit cell proliferation.

[00144] In vitro potency of small molecule inhibitors is determined, for example, by assaying human ovarian cancer cells (SKOV3) for viability following a 72-hour exposure to a 9-point dilution series of compound. Cell viability is determined by measuring the absorbance of formazon, a product formed by the bioreduction of MTS/PMS, a commercially available reagent. Each point on the dose-response curve is calculated as a percent of untreated control cells at 72 hours minus background absorption (complete cell kill).

[00145] Anti-proliferative compounds that have been successfully applied in the clinic to treatment of cancer (cancer chemotherapeutics) have GI₅₀'s that vary greatly. For example, in A549 cells, paclitaxel GI₅₀ is 4 nM, doxorubicin is 63 nM, 5-fluorouracil is 1 μM, and hydroxyurea is 500 μM (data provided by National Cancer Institute, Developmental Therapeutic Program, <http://dtp.nci.nih.gov/>). Therefore, compounds that inhibit cellular proliferation, irrespective of the concentration demonstrating inhibition, have potential clinical usefulness.

[00146] To employ the compounds of the invention in a method of screening for compounds that bind to KSP kinesin, the KSP is bound to a support, and a compound of the invention is added to the assay. Alternatively, the compound of the invention is bound to the support and KSP is added. Classes of compounds among which novel binding agents can be sought include specific antibodies, non-natural binding agents identified in screens of chemical libraries, peptide analogs, etc. Of particular interest are screening assays for candidate agents that have a low toxicity for human cells. A wide variety of assays can be used for this purpose, including labeled in vitro protein-protein binding assays, electrophoretic mobility shift assays, immunoassays for protein binding, functional assays (phosphorylation assays, etc.) and the like.

[00147] The determination of the binding of the compound of the invention to KSP can be done in a number of ways. In one embodiment, the compound is labeled, for example, with a fluorescent or radioactive moiety, and binding is determined directly. For example, this can be done by attaching all or a portion of KSP to a solid support, adding a labeled test compound (for example a compound of the invention in which at least one atom has been replaced by a detectable isotope), washing off excess reagent, and determining whether the amount of the label is that present on the solid support.

[00148] By "labeled" herein is meant that the compound is either directly or indirectly labeled with a label which provides a detectable signal, e.g., radioisotope, fluorescent tag, enzyme, antibodies, particles such as magnetic particles, chemiluminescent tag, or specific binding molecules, etc. Specific binding molecules include pairs, such as biotin and streptavidin, digoxin and antidigoxin etc. For the specific binding members, the complementary member would normally be labeled with a molecule which provides for detection, in accordance with known procedures, as outlined herein. The label can directly or indirectly provide a detectable signal.

[00149] In some embodiments, only one of the components is labeled. For example, the kinesin proteins can be labeled at tyrosine positions using ^{125}I , or with fluorophores. Alternatively, more than one component can be labeled with different labels; using ^{125}I for the proteins, for example, and a fluorophor for the antimitotic agents.

[00150] The compounds of the invention can also be used as competitors to screen for additional drug candidates. "Candidate agent" or "drug candidate" or grammatical equivalents as used herein describe any molecule, e.g., protein, oligopeptide, small organic molecule, polysaccharide, polynucleotide, etc., to be tested for bioactivity. They can be capable of directly or indirectly altering the cellular proliferation phenotype or the expression of a cellular proliferation sequence, including both nucleic acid sequences and protein sequences. In other cases, alteration of cellular proliferation protein binding and/or activity is screened. Screens of this sort can be performed either in the presence or absence of microtubules. In the case where protein binding or activity is screened, particular embodiments exclude molecules already known to bind to that particular protein, for example, polymer structures such as microtubules, and energy sources such as ATP. Particular embodiments of assays herein include candidate agents which do not bind the cellular proliferation protein in its endogenous native state termed herein as "exogenous" agents. In another embodiment, exogenous agents further exclude antibodies to KSP.

[00151] Candidate agents can encompass numerous chemical classes, though typically they are small organic compounds having a molecular weight of more than 100 and less than about 2,500 daltons. Candidate agents comprise functional groups necessary for structural interaction with proteins, particularly hydrogen bonding and lipophilic binding, and typically include at least an amine, carbonyl-, hydroxyl-, ether,

or carboxyl group, generally at least two of the functional chemical groups. The candidate agents often comprise cyclical carbon or heterocyclic structures and/or aromatic or polyaromatic structures substituted with one or more of the above functional groups. Candidate agents are also found among biomolecules including peptides, saccharides, fatty acids, steroids, purines, pyrimidines, derivatives, structural analogs or combinations thereof.

[00152] Candidate agents are obtained from a wide variety of sources including libraries of synthetic or natural compounds. For example, numerous means are available for random and directed synthesis of a wide variety of organic compounds and biomolecules, including expression of randomized oligonucleotides. Alternatively, libraries of natural compounds in the form of bacterial, fungal, plant and animal extracts are available or readily produced. Additionally, natural or synthetically produced libraries and compounds are readily modified through conventional chemical, physical and biochemical means. Known pharmacological agents can be subjected to directed or random chemical modifications, such as acylation, alkylation, esterification, and/or amidification to produce structural analogs.

[00153] Competitive screening assays can be done by combining KSP and a drug candidate in a first sample. A second sample comprises a compound of the present invention, KSP and a drug candidate. This can be performed in either the presence or absence of microtubules. The binding of the drug candidate is determined for both samples, and a change, or difference in binding between the two samples indicates the presence of a drug candidate capable of binding to KSP and potentially inhibiting its activity. That is, if the binding of the drug candidate is different in the second sample relative to the first sample, the drug candidate is capable of binding to KSP.

[00154] In a particular embodiment, the binding of the candidate agent to KSP is determined through the use of competitive binding assays. In this embodiment, the competitor is a binding moiety known to bind to KSP, such as an antibody, peptide, binding partner, ligand, etc. Under certain circumstances, there can be competitive binding as between the candidate agent and the binding moiety, with the binding moiety displacing the candidate agent.

[00155] In one embodiment, the candidate agent is labeled. Either the candidate agent, or the competitor, or both, is added first to KSP for a time sufficient

to allow binding, if present. Incubations can be performed at any temperature which facilitates optimal activity, typically between 4 and 40°C.

[00156] Incubation periods are selected for optimum activity, but can also be optimized to facilitate rapid high throughput screening. Typically between 0.1 and 1 hour will be sufficient. Excess reagent is generally removed or washed away. The second component is then added, and the presence or absence of the labeled component is followed, to indicate binding.

[00157] In another embodiment, the competitor is added first, followed by the candidate agent. Displacement of the competitor is an indication the candidate agent is binding to KSP and thus is capable of binding to, and potentially inhibiting, the activity of KSP. In this embodiment, either component can be labeled. Thus, for example, if the competitor is labeled, the presence of label in the wash solution indicates displacement by the agent. Alternatively, if the candidate agent is labeled, the presence of the label on the support indicates displacement.

[00158] In an alternative embodiment, the candidate agent is added first, with incubation and washing, followed by the competitor. The absence of binding by the competitor can indicate the candidate agent is bound to KSP with a higher affinity. Thus, if the candidate agent is labeled, the presence of the label on the support, coupled with a lack of competitor binding, can indicate the candidate agent is capable of binding to KSP.

[00159] Inhibition is tested by screening for candidate agents capable of inhibiting the activity of KSP comprising the steps of combining a candidate agent with KSP, as above, and determining an alteration in the biological activity of KSP. Thus, in this embodiment, the candidate agent should both bind to KSP (although this may not be necessary), and alter its biological or biochemical activity as defined herein. The methods include both in vitro screening methods and in vivo screening of cells for alterations in cell cycle distribution, cell viability, or for the presence, morphology, activity, distribution, or amount of mitotic spindles, as are generally outlined herein.

[00160] Alternatively, differential screening can be used to identify drug candidates that bind to the native KSP, but cannot bind to modified KSP.

[00161] Positive controls and negative controls can be used in the assays. Suitably all control and test samples are performed in at least triplicate to obtain

statistically significant results. Incubation of all samples is for a time sufficient for the binding of the agent to the protein. Following incubation, all samples are washed free of non-specifically bound material and the amount of bound, generally labeled agent determined. For example, where a radiolabel is employed, the samples can be counted in a scintillation counter to determine the amount of bound compound.

[00162] A variety of other reagents can be included in the screening assays. These include reagents like salts, neutral proteins, e.g., albumin, detergents, etc which can be used to facilitate optimal protein-protein binding and/or reduce non-specific or background interactions. Also reagents that otherwise improve the efficiency of the assay, such as protease inhibitors, nuclease inhibitors, anti-microbial agents, etc., can be used. The mixture of components can be added in any order that provides for the requisite binding.

Administration

[00163] Accordingly, the compounds of the invention are administered to cells. By "administered" herein is meant administration of a therapeutically effective dose of a compound of the invention to a cell either in cell culture or in a patient. By "therapeutically effective dose" herein is meant a dose that produces the effects for which it is administered. The exact dose will depend on the purpose of the treatment, and will be ascertainable by one skilled in the art using known techniques. As is known in the art, adjustments for systemic versus localized delivery, age, body weight, general health, sex, diet, time of administration, drug interaction and the severity of the condition may be necessary, and will be ascertainable with routine experimentation by those skilled in the art. By "cells" herein is meant any cell in which mitosis or meiosis can be altered.

[00164] A "patient" for the purposes of the present invention includes both humans and other animals, particularly mammals, and other organisms. Thus the methods are applicable to both human therapy and veterinary applications. In a particular embodiment the patient is a mammal, and more particularly, the patient is human.

[00165] Compounds of the invention having the desired pharmacological activity can be administered, especially as a pharmaceutically acceptable composition comprising an pharmaceutical excipient, to a patient, as described herein. Depending

upon the manner of introduction, the compounds can be formulated in a variety of ways as discussed below. The concentration of therapeutically active compound in the formulation can vary from about 0.1-100 wt.%.

[00166] The agents can be administered alone or in combination with other treatments, i.e., radiation, or other chemotherapeutic agents such as the taxane class of agents that appear to act on microtubule formation or the camptothecin class of topoisomerase I inhibitors. When used, other chemotherapeutic agents can be administered before, concurrently, or after administration of a compound of the present invention. In one aspect of the invention, a compound of the present invention is co-administered with one or more other chemotherapeutic agents. By "co-administer" it is meant that the present compounds are administered to a patient such that the present compounds as well as the co-administered compound can be found in the patient's bloodstream at the same time, regardless when the compounds are actually administered, including simultaneously.

[00167] The administration of the compounds and compositions of the present invention can be done in a variety of ways, including, but not limited to, orally, subcutaneously, intravenously, intranasally, transdermally, intraperitoneally, intramuscularly, intrapulmonary, vaginally, rectally, or intraocularly. In some instances, for example, in the treatment of wounds and inflammation, the compound or composition can be directly applied as a solution or spray.

[00168] Pharmaceutical dosage forms include a compound of Formula I or a pharmaceutically acceptable salt, solvate, or solvate of a salt thereof, and one or more pharmaceutical excipients. As is known in the art, pharmaceutical excipients are secondary ingredients which function to enable or enhance the delivery of a drug or medicine in a variety of dosage forms (e.g.: oral forms such as tablets, capsules, and liquids; topical forms such as dermal, ophthalmic, and otic forms; suppositories; injectables; respiratory forms and the like). Pharmaceutical excipients include inert or inactive ingredients, synergists or chemicals that substantively contribute to the medicinal effects of the active ingredient. For example, pharmaceutical excipients can function to improve flow characteristics, product uniformity, stability, taste, or appearance, to ease handling and administration of dose, for convenience of use, or to control bioavailability. While pharmaceutical excipients are commonly described as being inert or inactive, it is appreciated in the art that there is a relationship between

the properties of the pharmaceutical excipients and the dosage forms containing them.

[00169] Pharmaceutical excipients suitable for use as carriers or diluents are well known in the art, and can be used in a variety of formulations. See, e.g., Remington's Pharmaceutical Sciences, 18th Edition, A. R. Gennaro, Editor, Mack Publishing Company (1990); Remington: The Science and Practice of Pharmacy, 20th Edition, A. R. Gennaro, Editor, Lippincott Williams & Wilkins (2000); Handbook of Pharmaceutical Excipients, 3rd Edition, A. H. Kibbe, Editor, American Pharmaceutical Association, and Pharmaceutical Press (2000); and Handbook of Pharmaceutical Additives, compiled by Michael and Irene Ash, Gower (1995), each of which is incorporated herein by reference for all purposes.

[00170] Oral solid dosage forms such as tablets will typically comprise one or more pharmaceutical excipients, which can for example help impart satisfactory processing and compression characteristics, or provide additional desirable physical characteristics to the tablet. Such pharmaceutical excipients can be selected from diluents, binders, glidants, lubricants, disintegrants, colors, flavors, sweetening agents, polymers, waxes or other solubility-retarding materials.

[00171] Compositions for intravenous administration will generally comprise intravenous fluids, i.e., sterile solutions of simple chemicals such as sugars, amino acids or electrolytes, which can be easily carried by the circulatory system and assimilated. Such fluids are prepared with water for injection USP.

[00172] Dosage forms for parenteral administration will generally comprise fluids, particularly intravenous fluids, i.e., sterile solutions of simple chemicals such as sugars, amino acids or electrolytes, which can be easily carried by the circulatory system and assimilated. Such fluids are typically prepared with water for injection USP. Fluids used commonly for intravenous (IV) use are disclosed in Remington, The Science and Practice of Pharmacy [full citation previously provided], and include:

- alcohol, e.g., 5% alcohol (e.g., in dextrose and water ("D/W") or D/W in normal saline solution ("NSS"), including in 5% dextrose and water ("D5/W"), or D5/W in NSS);
- synthetic amino acid such as Aminosyn, FreAmine, Travasol, e.g., 3.5 or 7; 8.5; 3.5, 5.5 or 8.5 % respectively;
- ammonium chloride e.g., 2.14%;
- dextran 40, in NSS e.g., 10% or in D5/W e.g., 10%;

- dextran 70, in NSS e.g., 6% or in D5/W e.g., 6%;
- dextrose (glucose, D5/W) e.g., 2.5-50%;
- dextrose and sodium chloride e.g., 5-20% dextrose and 0.22-0.9% NaCl;
- lactated Ringer's (Hartmann's) e.g., NaCl 0.6%, KCl 0.03%, CaCl₂ 0.02%;
- lactate 0.3%;
- mannitol e.g., 5%, optionally in combination with dextrose e.g., 10% or NaCl e.g., 15 or 20%;
- multiple electrolyte solutions with varying combinations of electrolytes, dextrose, fructose, invert sugar Ringer's e.g., NaCl 0.86%, KCl 0.03%, CaCl₂ 0.033%;
- sodium bicarbonate e.g., 5%;
- sodium chloride e.g., 0.45, 0.9, 3, or 5%;
- sodium lactate e.g., 1/6 M; and
- sterile water for injection

The pH of such IV fluids can vary, and will typically be from 3.5 to 8 as known in the art.

[00173] The compounds, pharmaceutically acceptable salts and solvates of the invention can be administered alone or in combination with other treatments, i.e., radiation, or other therapeutic agents, such as the taxane class of agents that appear to act on microtubule formation or the camptothecin class of topoisomerase I inhibitors. When so-used, other therapeutic agents can be administered before, concurrently (whether in separate dosage forms or in a combined dosage form), or after administration of an active agent of the present invention.

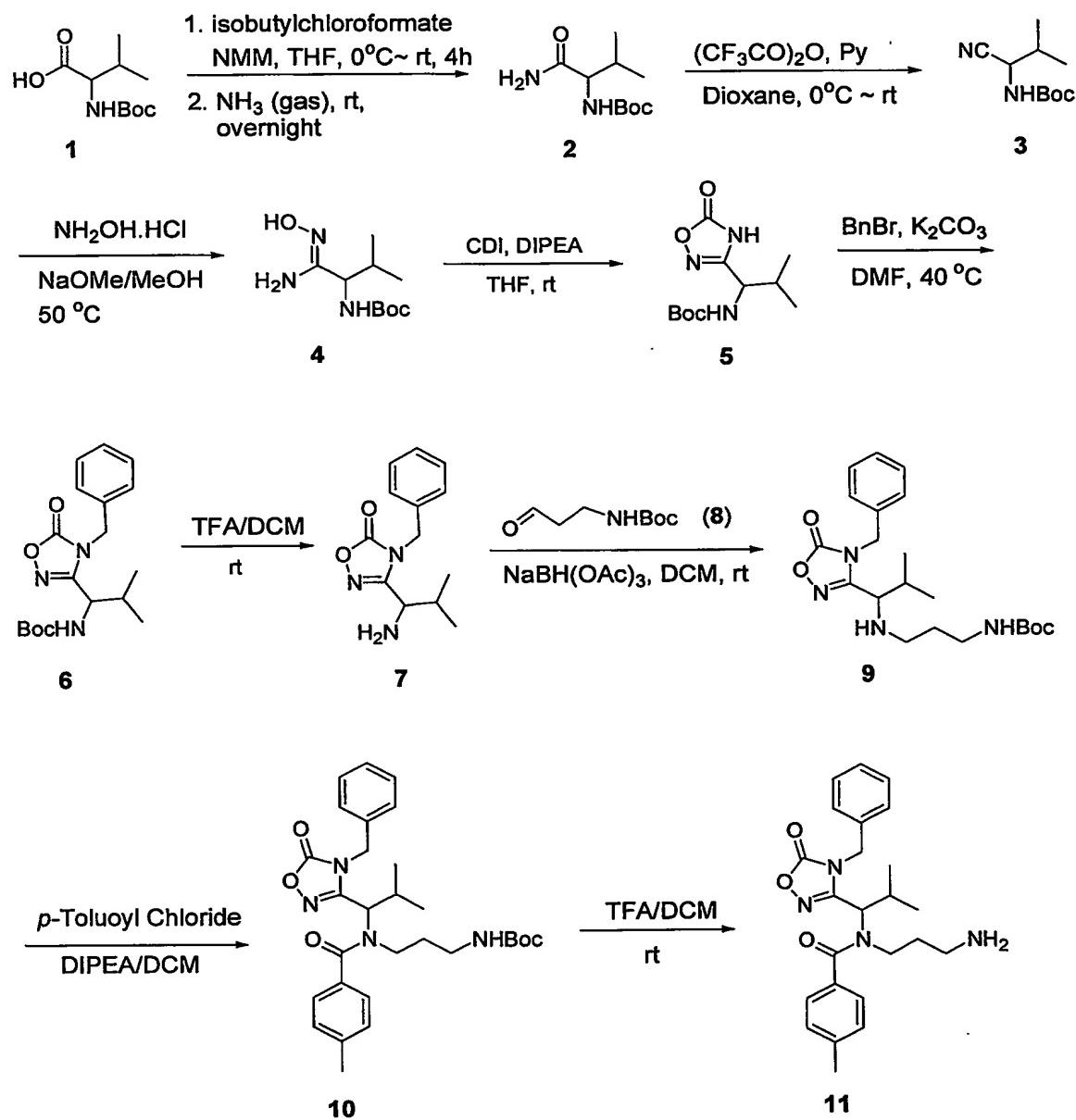
[00174] The following examples serve to more fully describe the manner of using the above-described invention. It is understood that these examples in no way serve to limit the true scope of this invention, but rather are presented for illustrative purposes. All publications, including but not limited to patents and patent applications, cited in this specification are herein incorporated by reference as if each individual publication were specifically and individually indicated to be incorporated by reference herein.

EXAMPLES

[00175] All anhydrous solvents were purchased from Aldrich Chemical Company in SureSeal® containers.

Example 1

Synthesis of Compounds



[00176] To a solution of *N*-Boc-DL-Val-OH (11.0 g, 50.0 mmol) and *N*-methyl morpholine (7.5 mL, 70.0 mmol) in anhydrous tetrahydrofuran (300 mL) at 0 °C was added *iso*-butyl chloroformate (8.5 mL, 66.0 mmol). The resulting mixture was stirred at room temperature for 4 hours. The flask was then equipped with a dry-ice reflux condenser and purged continuously with gaseous ammonia for 2 hours. The resulting reaction mixture was then stirred at room temperature overnight. After most of the solvent was removed *in vacuo*, the residue was diluted with saturated aqueous sodium bicarbonate solution and extracted with ethyl acetate (3 x 100 mL). The combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The residue (10.8 g) was confirmed to be the desired amide 2 by ¹H-NMR and LC/MS (LRMS (MH) *m/z* 216.28) and was used for the subsequent transformation without purification.

[00177] To a room temperature solution of amide 2 (1.2 g, 5.0 mmol) in dioxane (20 mL) were added pyridine (1.0 mL, 12.5 mmol) and trifluoroacetic anhydride (1.41 mL, 10.0 mmol), successively. The resulting solution was stirred for 4 hours and then quenched with saturated aqueous sodium bicarbonate solution and extracted with ethyl acetate (3 x 100 mL). The combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The residue was purified by flash chromatography (silica gel, Hexane/ethyl acetate), and the desired compound 3 (1.0 g) was isolated and characterized by ¹H-NMR and LC/MS (LRMS (MH) *m/z* 198.26).

[00178] To a room temperature solution of intermediate 3 (1.0 g, 5.0 mmol) in methanol (10 mL) were added a solution of sodium methoxide (20 mL, 0.5 M) and hydroxylamine hydrochloride (690 mg, 10.0 mmol), successively. The resulting solution was heated to 50 °C overnight and then cooled to room temperature. It was then quenched with saturated aqueous sodium bicarbonate solution, and most of the solvents were removed *in vacuo*. The residue was saturated with sodium chloride and extracted with tetrahydrofuran (3 x 60 mL). The combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The desired product 4 (560 mg) was characterized by ¹H-NMR and LC/MS (LRMS (MH) *m/z*: 232.29) and used in the subsequent transformation without purification.

[00179] To a room temperature solution of intermediate 4 (750 mg, 3.3 mmol) in tetrahydrofuran (30 mL) were added diisopropylethylamine (1 mL) and 1,1'-

carbonyldiimidazole (580 mg, 3.7 mmol). The resulting solution was stirred for 4 hours and then quenched with saturated aqueous sodium bicarbonate solution. Most of the solvents were removed *in vacuo*, and the residue was extracted with ethyl acetate (3 x 60 mL). The combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The residue was purified by flash chromatography (silica gel, dichloromethane/methanol), and the desired oxadiazolone 5 (560 mg) was isolated and characterized by ¹H-NMR and LC/MS (LRMS (MH) *m/z*: 258.29).

[00180] To a room temperature solution of intermediate 5 (880 mg, 3.4 mmol) in *N,N*-dimethylformamide (25 mL) were added potassium carbonate (1.88 g, 13.6 mmol) and benzyl bromide (820 μ L, 6.8 mmol). The resulting suspension was stirred at 40 °C for 6 hours. It was quenched with saturated aqueous sodium bicarbonate solution and extracted with ethyl acetate (3 x 60 mL). The combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The residue was purified by flash chromatography (silica gel, dichloromethane/methanol), and the desired oxadiazolone 6 (550 mg) was isolated and characterized by ¹H-NMR and LC/MS (LRMS (MH) *m/z*: 348.41).

[00181] To a solution of intermediate 6 (550 mg 1.58 mmol) in dichloromethane (30 mL) at 0 °C was added trifluoroacetic acid (10 mL). The resulting solution was stirred at room temperature for 1 hour. Most of solvents were then removed *in vacuo*, and the residue was dried under high vacuum for 1 hour, diluted with ethyl acetate (50 mL) and washed with saturated sodium bicarbonate solution (25 mL). The aqueous phase was extracted with ethyl acetate (3 x 25 mL), and the combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The residue 7 (450 mg) was used in the next step without further purification. Compound 7 was characterized by ¹H-NMR and LC/MS (LRMS (MH) *m/z*: 248.29).

[00182] To a room temperature solution of free amine 7 (450 mg, 1.82 mmol) in dichloromethane (15 mL) were added sodium triacetoxyborohydride (500 mg, 2.20 mmol) and aldehyde 8 (378 mg, 2.20 mmol), successively. The resulting mixture was stirred at the same temperature under nitrogen for 12 hours. It was then quenched with saturated aqueous sodium bicarbonate solution, and the aqueous phase was extracted with dichloromethane (3 x 60 mL). The combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The residue was purified by flash chromatography (silica gel, dichloromethane/methanol), and the desired product 9

(420 mg) was isolated and characterized by LC/MS (LRMS (MH) *m/z* 405.50).

[00183] To a solution of oxadiazolone **9** (420 mg, 1.0 mmol) in dichloromethane (20 mL) at 0 °C were added diisopropylethylamine (1.0 mL) and *p*-toluoyl chloride (187 mg, 1.0 mmol), successively. The resulting solution was stirred at room temperature under nitrogen overnight. It was quenched with saturated aqueous sodium bicarbonate solution, and the aqueous phase was extracted with ethyl acetate (4 x 50 mL). The combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The residue was purified by flash column chromatography (silica gel, dichloromethane and methanol), and the desired product **10** (500 mg) was isolated and characterized by ¹H-NMR and LC/MS (LRMS (MH) *m/z*: 523.64).

[00184] To a solution of oxadiazolone **10** (500 mg, 0.96 mmol) in dichloromethane (20 mL) at 0 °C was added trifluoroacetic acid (6 mL). The resulting solution was stirred at room temperature for 2 hours and then concentrated *in vacuo*. The residue was dried under high vacuum for one hour and dissolved in ethyl acetate (50 mL). The resulting solution was washed with saturated aqueous sodium bicarbonate solution, and the aqueous phase was extracted with ethyl acetate (3 x 50 mL). The combined organic layers were dried over sodium sulfate and concentrated *in vacuo*. The residue was purified by flash column chromatography (silica gel, methanol/dichloromethane), and the desired product **11** (245 mg) was isolated and characterized by ¹H-NMR and LC/MS analysis (LRMS (MH) *m/z*: 423.54).

Example 2

Monopolar Spindle Formation following Application of a KSP Inhibitor

[00185] Human tumor cells Skov-3 (ovarian) were plated in 96-well plates at densities of 4,000 cells per well, allowed to adhere for 24 hours, and treated with various concentrations of the compounds of the invention for 24 hours. Cells were fixed in 4% formaldehyde and stained with antitubulin antibodies (subsequently recognized using fluorescently-labeled secondary antibody) and Hoechst dye (which stains DNA).

[00186] Visual inspection revealed that the compounds caused cell cycle arrest in the prometaphase stage of mitosis. DNA was condensed and spindle formation had initiated, but arrested cells uniformly displayed monopolar spindles, indicating that there was an inhibition of spindle pole body separation. Microinjection of anti-KSP

antibodies also causes mitotic arrest with arrested cells displaying monopolar spindles.

Example 3

Inhibition of Cellular Proliferation in Tumor Cell Lines

[00187] Cells were plated in 96-well plates at densities from 1000-2500 cells/well of a 96-well plate and allowed to adhere/grow for 24 hours. They were then treated with various concentrations of drug for 48 hours. The time at which compounds are added is considered T_0 . A tetrazolium-based assay using the reagent 3-(4,5-dimethylthiazol-2-yl)-5-(3-carboxymethoxyphenyl)-2-(4-sulfophenyl)-2H-tetrazolium (MTS) (I.S> Patent No. 5,185,450) (see Promega product catalog #G3580, CellTiter 96® AQ_{ueous} One Solution Cell Proliferation Assay) was used to determine the number of viable cells at T_0 and the number of cells remaining after 48 hours compound exposure. The number of cells remaining after 48 hours was compared to the number of viable cells at the time of drug addition, allowing for calculation of growth inhibition.

[00188] The growth over 48 hours of cells in control wells that had been treated with vehicle only (0.25% DMSO) is considered 100% growth and the growth of cells in wells with compounds is compared to this. KSP inhibitors inhibited cell proliferation in human ovarian tumor cell lines (SKOV-3).

[00189] A Gi_{50} was calculated by plotting the concentration of compound in μM vs the percentage of cell growth of cell growth in treated wells. The Gi_{50} calculated for the compounds is the estimated concentration at which growth is inhibited by 50% compared to control, i.e., the concentration at which:

$$100 \times [(Treated_{48} - T_0) / (Control_{48} - T_0)] = 50.$$

[00190] All concentrations of compounds are tested in duplicate and controls are averaged over 12 wells. A very similar 96-well plate layout and Gi_{50} calculation scheme is used by the National Cancer Institute (see Monks, et al., J. Natl. Cancer Inst. 83:757-766 (1991)). However, the method by which the National Cancer Institute quantitates cell number does not use MTS, but instead employs alternative methods.

Example 4

Calculation of IC_{50} :

[00191] Measurement of a composition's IC₅₀ for KSP activity uses an ATPase assay. The following solutions are used: Solution 1 consists of 3 mM phosphoenolpyruvate potassium salt (Sigma P-7127), 2 mM ATP (Sigma A-3377), 1 mM IDTT (Sigma D-9779), 5 µM paclitaxel (Sigma T-7402), 10 ppm antifoam 289 (Sigma A-8436), 25 mM Pipes/KOH pH 6.8 (Sigma P6757), 2 mM MgC12 (VWR JT400301), and 1 mM EGTA (Sigma E3889). Solution 2 consists of 1 mM NADH (Sigma N8129), 0.2 mg/ml BSA (Sigma A7906), pyruvate kinase 7U/ml, L-lactate dehydrogenase 10 U/ml (Sigma P0294), 100 nM KSP motor domain, 50 µg/ml microtubules, 1 mM DTT (Sigma D9779), 5 µM paclitaxel (Sigma T-7402), 10 ppm antifoam 289 (Sigma A-8436), 25 mM Pipes/KOH pH 6.8 (Sigma P6757), 2 mM MgC12 (VWR JT4003-01), and 1 mM EGTA (Sigma E3889). Serial dilutions (8-12 two-fold dilutions) of the composition are made in a 96-well microtiter plate (Corning Costar 3695) using Solution 1. Following serial dilution each well has 50 µl of Solution 1. The reaction is started by adding 50 µl of solution 2 to each well. This may be done with a multichannel pipettor either manually or with automated liquid handling devices. The microtiter plate is then transferred to a microplate absorbance reader and multiple absorbance readings at 340 nm are taken for each well in a kinetic mode. The observed rate of change, which is proportional to the ATPase rate, is then plotted as a function of the compound concentration. For a standard IC₅₀ determination the data acquired is fit by the following four parameter equation using a nonlinear fitting program (e.g., Grafit 4):

$$y = \frac{\text{Range}}{1 + \left(\frac{x}{IC_{50}}\right)^s} + \text{Background}$$

where y is the observed rate and x the compound concentration.

[00192] Other compounds of this class were found to inhibit cell proliferation, although GI₅₀ values varied. GI₅₀ values for the compounds tested ranged from 200 nM to greater than the highest concentration tested. By this we mean that although most of the compounds that inhibited KSP activity biochemically did inhibit cell proliferation, for some, at the highest concentration tested (generally about 20 µM), cell growth was inhibited less than 50%. Many of the compounds have GI₅₀ values less than 10 µM, and several have GI₅₀ values less than 1 µM. Anti-proliferative

compounds that have been successfully applied in the clinic to treatment of cancer (cancer chemotherapeutics) have GI₅₀'s that vary greatly. For example, in A549 cells, paclitaxel GI₅₀ is 4 nM, doxorubicin is 63 nM, 5-fluorouracil is 1 μM, and hydroxyurea is 500 μM (data provided by National Cancer Institute, Developmental Therapeutic Program, <http://dtp.nci.nih.gov/>). Therefore, compounds that inhibit cellular proliferation at virtually any concentration may be useful. However, preferably, compounds will have GI₅₀ values of less than 1 mM. More preferably, compounds will have GI₅₀ values of less than 20 μM. Even more preferably, compounds will have GI₅₀ values of less than 10 μM. Further reduction in GI₅₀ values may also be desirable, including compounds with GI₅₀ values of less than 1 μM. Some of the compounds of the invention inhibit cell proliferation with GI₅₀ values from below 200 nM to below 10 nM.